BBC

6 starry sights for binoculars

Brian Cox's *The Planets* Inside the new TV series

#169 JUNE 2019

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

SUMMER TOUR THE DEEP SKY

Your expert guide to observing this month's best star clusters, nebulae and galaxies

SPECIAL REPORT

Historic first image of a black hole

ASTEROID ALERT

Why the threat of impact is always evolving

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Welcome

The black hole image hails an era of planet-wide observing

The press conference to release the historic first image of a black hole in April had us all glued to our screens here at the magazine. We watched as the remarkable achievement – a picture which took two years to process – was unveiled, proof that all the simulations and artists impressions of black holes were correct.

With a shiver we had come face to face with an object that even Einstein had doubted the existence of. For the inside story of how this observation was achieved and the planet-wide network of radio telescopes that produced it, turn to page 26. There's also insight from a UK member of the Event Horizon Telescope team on page 14 and a look at Messier 87, the galaxy in which the black hole lies, on page 6.

Something else to have us glued to our screens this summer is *The Planets*, the new series presented by Brian Cox coming to BBC Two. It's a full tour of our planetary system and a stunning high-definition look at how far our knowledge of the other worlds orbiting the Sun has come, now that we've completed an initial scientific survey of them. We went to an early screening at the BBC and spoke to Brian Cox; read our interview and discover more on page 30.

Staying with the planets, Jupiter is at opposition on 10 June and at its brightest this apparition. There are some nice moon and shadow transits across the gas giant to observe, and Saturn, Mercury, Venus and Mars are also on view. You'll find full planetary observing details and a glorious tour of summer deep sky delights in the Sky Guide from page 43.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale 20 June.

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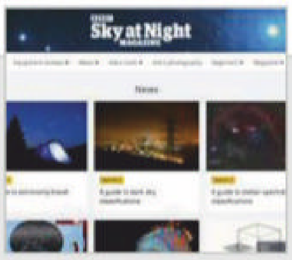
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team will be exploring in this month's episode on page 14



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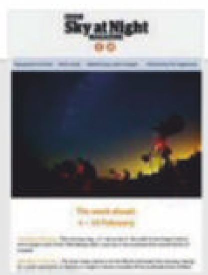

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C = on the cover

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New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Sandra Kropa
Astronomy journalist

Sandra discovers the challenges astronomers keeping track of the asteroid threat face. See page 70

Govert Schilling
Space writer

Imaging a cosmic monster like a black hole is no small feat. Govert finds out how it was done. See page 26

Will Gater
Astrophotographer

Will give tips on using nightscapes to image planets when they're low in the sky. See page 36

Emily Winterburn
Historian of astronomy

Emily reviews Daniel Kennefick's book that links the 1919 eclipse and Einstein. Turn to page 94

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/t6kp9du/** to access this month's Bonus Content.

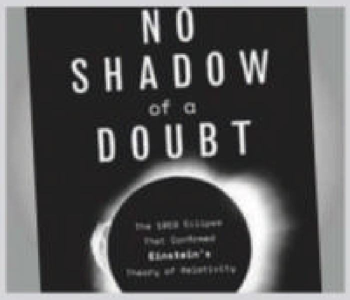
June highlights

Watch The Sky at Night

The team look at InSight, NASA's latest lander on Mars, which is searching for shuddering quakes below the Red Planet's surface. And for stargazers, Mars isn't the only tinted celestial object visible. Pete Lawrence reveals how to spot other colourful bodies in the night sky.

Interview: get ready for Asteroid Day

Danica Remy, co-founder of Asteroid Day, talks the science of space rocks and why she's making them a global priority.

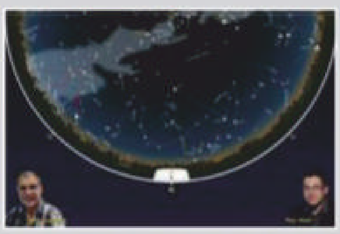


Audio book preview: No Shadow of a Doubt

Listen to an audio excerpt from a new book about astronomers Dyson and Eddington's historic 1919 eclipse expedition.

Hotshots gallery, extra EQMOD files, binocular tour, observing forms, deep-sky tour chart, desktop wallpapers...**and much more**

PLUS: Every month



The virtual planetarium

June's night-sky highlights with Paul Abel and Pete Lawrence

NASA/JPL-CALTECH/IPAC

Illuminating the invisible

If you want to image a black hole, how do you know where to find one? Luckily these invisible objects have tell-tale signs for astronomers

SPITZER SPACE TELESCOPE, 25 APRIL 2019

This is galaxy M87, home of the supermassive black hole that became one of the biggest stories of the year when it was imaged by astronomers using the Event Horizon Telescope.

One clue that there is a supermassive black hole at the galaxy's centre can be seen in this image: jets of material shooting outwards from the core. As the jets hit interstellar material they generate a huge shockwave, one of which appears here as a finger-like object emanating to the right of the bright centre. A fainter shockwave can also be seen shooting out to the left.

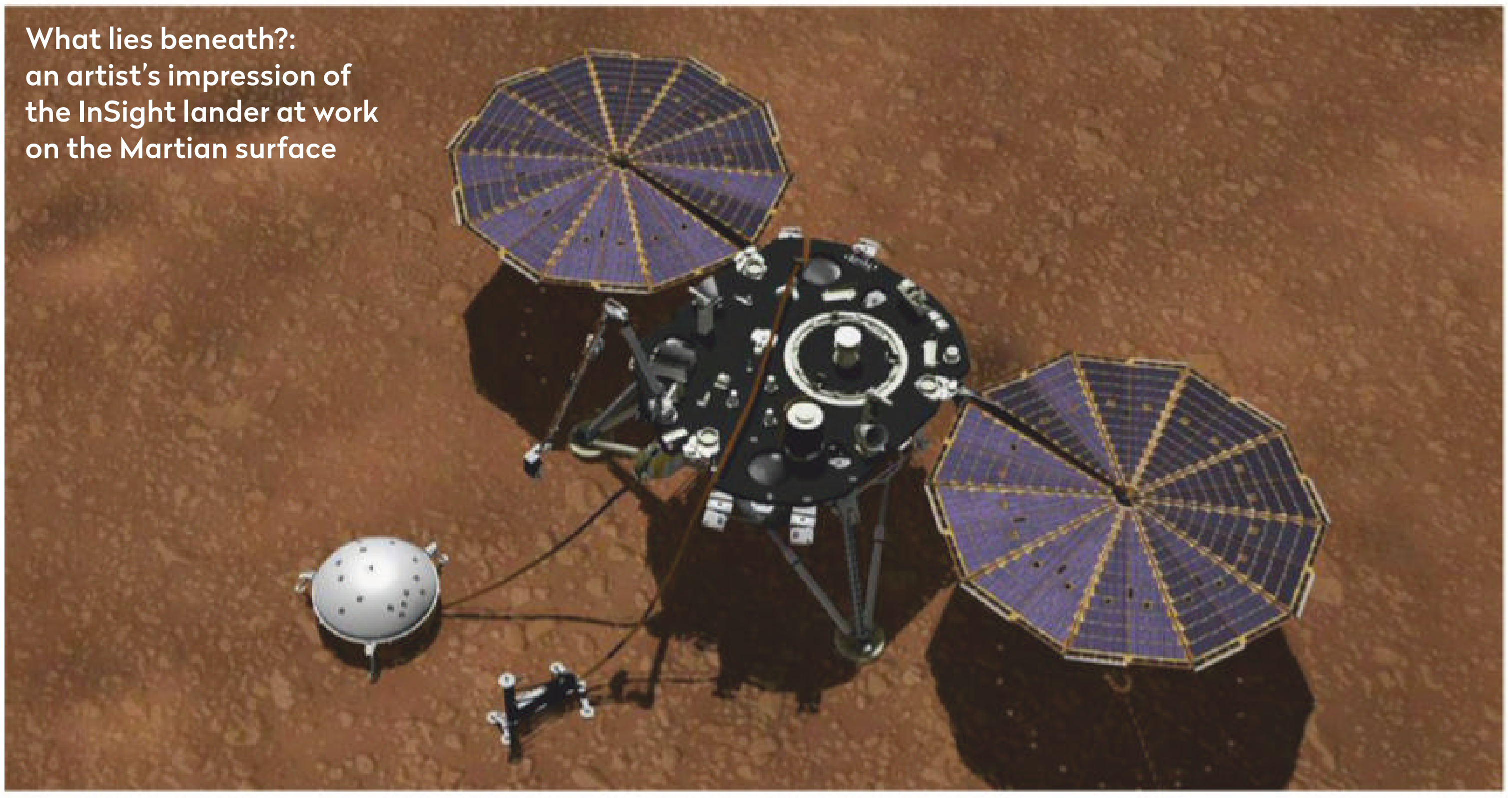
This may go against the view of black holes as cosmic vacuum cleaners, but supermassive black holes are surrounded by a disc of spinning matter and, if the black hole consumes this matter rapidly, the material heats up as it falls inwards, causing it to shine brightly. The process contributes to the bright regions seen at the centres of many galaxies. The infalling matter is also responsible for producing jets like those seen in this image, although exactly how this occurs is not fully known.

It is thought there is a supermassive black hole at the centre of most galaxies, and the new image of M87's central black hole is a major stepping stone to understanding these mind-blowing objects and their place in the Universe. Read more on p26, where Govert Schilling reveals the story behind the first ever image captured of a black hole and what the achievement means for astronomy.

More ONLINE
A gallery of this and more stunning space images

InSight lander detects its first MARSQUAKE

The lander will spend a Martian year monitoring the planet's interior



What lies beneath?: an artist's impression of the InSight lander at work on the Martian surface

The InSight lander detected the first ever Martian seismic event, known as a marsquake, on 6 April 2019.

"This is what we were all waiting for, the first quivering of the planet picked up by our sensors," says Tom Pike from Imperial College London, who led the UK involvement with InSight's Seismic Experiment for Interior Structure (SEIS), the instrument which made the discovery.

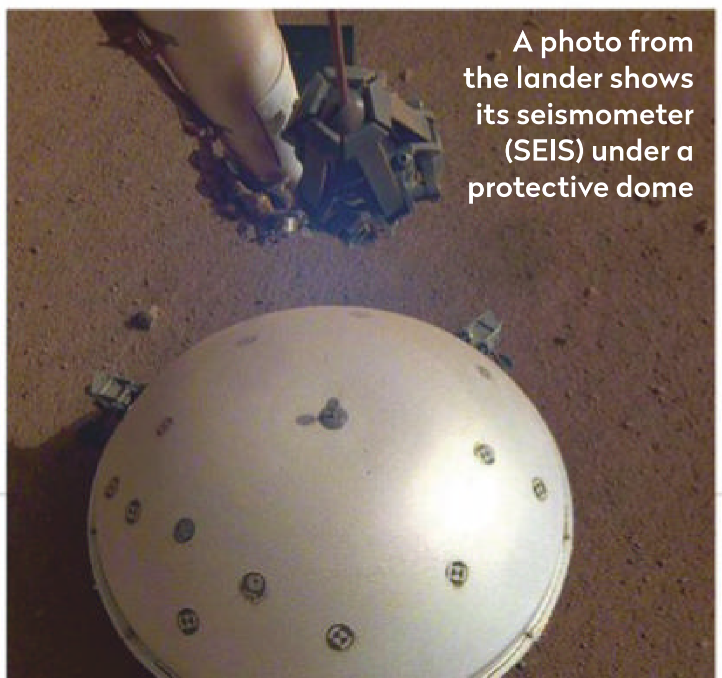
SEIS was deployed onto the Martian surface in December 2018 before being covered by a wind and thermal shield to reduce the background noise which masks the subtle vibrations of the planet.

"The signals are smaller than anything we would detect on Earth because there is much less background noise on Mars – no oceans, trees or people – and the seismicity of Mars is much lower than on Earth because we do not have plate tectonics on Mars," says Anna Horleston from the University of Bristol, who is part of the Marsquake Service, an international team which studies InSight's seismic data. "The complete package allows us to measure movements of the ground smaller than the width of a hydrogen atom."

Over the next Martian year, InSight will use seismometers, heat sensors and other instruments to examine the planet's internal structure to help understand Mars's history and evolution.

"On Mars, we see ancient volcanoes, huge canyons, dried up lake and river beds, and yet now there is no surface evidence of volcanism or liquid water," says Horleston. "How did Mars evolve from this dynamic wet planet to the dry dead planet we see now? That's what we hope to find out."

https://mars.nasa.gov/insight



A photo from the lander shows its seismometer (SEIS) under a protective dome

NASA/JPL-CALTECH X 2, JORGE VILLEGAS/XINHUA/ALAMY LIVE NEWS, UNIVERSITY OF WARWICK/MARK GARLICK, ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Comment

by Chris Lintott

I'm delighted for the InSight team now they've found their first marsquakes – even if I wish they'd done it just slightly earlier so we could have included them in our *Sky at Night* that featured the mission.

I watched the landing in front of a live audience with Anna Horleston. NASA called the decent to the Martian surface 'seven minutes of terror', and I felt for the team living out those scary moments.

The last few metres of descent seemed to take a lifetime, but once Insight was safely down, relief turned to excitement. It takes efforts, from thousands of people to get a mission like InSight to the point we're at now, where science can start to flow and Mars's secrets can be revealed.

Chris Lintott co-presents *The Sky at Night*

'A landmark of astronomy': the image of the black hole hits international headlines

World gets first glimpse of a black hole

The Event Horizon Telescope captures a cosmic phenomenon

After two years of processing, the Event Horizon Telescope has finally released the first ever image of a black hole on 10 April.

"We are giving humanity its first view of a black hole – a one-way door out of our Universe," says project director, Sheperd Doeleman from the University of Harvard. "This is a landmark in astronomy; an unprecedented scientific feat accomplished by a team of more than 200 researchers."

The image was taken in April 2017, when eight radio telescopes across the globe joined together, effectively creating an instrument with a dish the size of the planet. This gave it enough resolution to pick out the shadow of a supermassive black hole at the heart of galaxy M87.
eventhorizontelescope.org

▸ **To find out more about the image and how it was taken, turn to page 26.**

Powerful eruption comes from tiny star

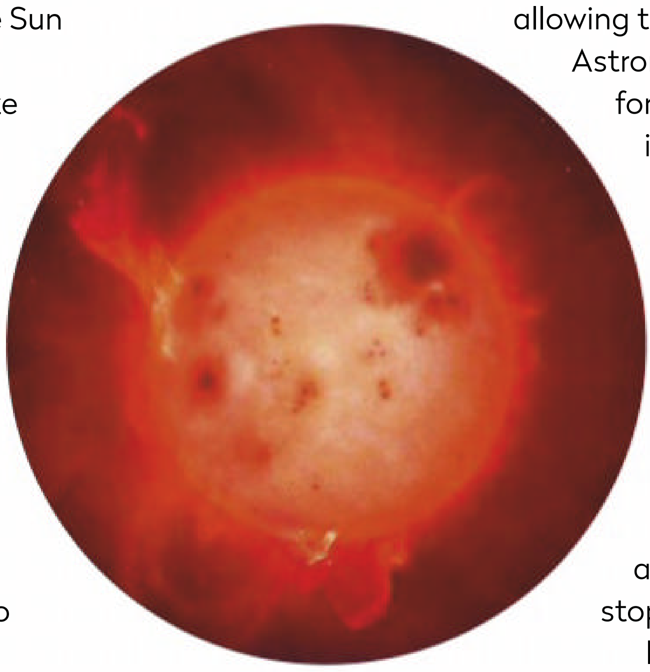
A flare 10 times more powerful than anything produced by the Sun has been spotted coming from a star roughly the size of Jupiter. The flare is estimated to be equivalent to 80 billion megatonnes of TNT.

"It's right on the boundary between being a star and a brown dwarf – a very low mass, substellar object," says James Jackman from the University of Warwick who led the study.

The star was previously unknown, when a flare on 12 August 2017 made it glow 10,000 times brighter than normal, allowing telescopes to detect it.

Astronomers observed the star for 146 nights, tracking how its brightness rose and fell, hoping to understand both the cause of the flare and how one of such size arose from a tiny star.

"By pushing this boundary, we can see whether these types of flares are limited to stars and if so, when this activity stops. This result takes us a long way to being able to answer these questions," says Jackman.
https://warwick.ac.uk



▲ An artist's impression of the flare which made a small star glow 10,000 times brighter than normal

NEWS IN BRIEF

Rosetta images released

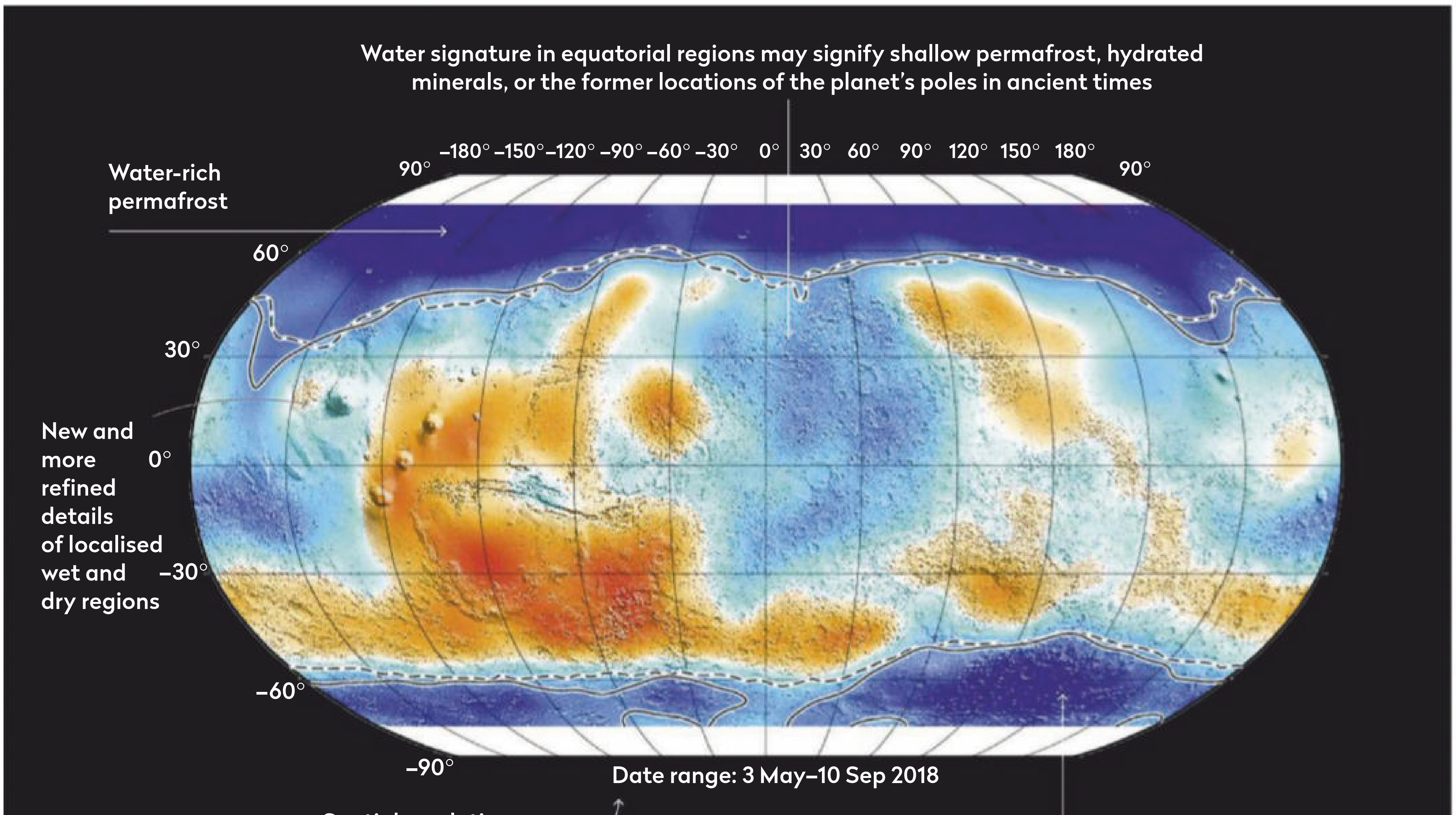
Over 70,000 images from the OSIRIS camera on ESA's Rosetta spacecraft are now available online. The spacecraft orbited comet 67P/Churyumov-Gerasimenko between 2014 and 2016 as it passed by the Sun. The images show both the comet's nucleus and the gas jets created by solar heating. The images can be found at rosetta-osiris.eu.

Inner planet's solid core

Mercury's inner-most core is solid, a new study has determined using data from NASA's MESSENGER mission. The spacecraft used radio observations to probe inside the planet, finding that even though the outer layers of the planet's massive iron core – which takes up 85 per cent of its volume – are liquid, its heart is solid.

Three planets, two stars

A new planet has been found in a planetary system which orbits around two stars, Kepler-47, making it the third in the system. The planet appears to be the largest in the star system, measuring seven times Earth's diameter, but it only recently moved into a favourable alignment to be identified.



Map of subsurface water distribution on Mars, as revealed by ESA's ExoMars orbiter

Looking for life on Mars

New results from Mars orbiter show water-rich locations that could reveal evidence of life

There's no methane on Mars, but there is lots of water (at least by Martian standards) according to the first results from ESA's ExoMars Trace Gas Orbiter (TGO), which were announced in April. The findings could have serious implications for the chances of finding life on the Red Planet.

"We are delighted with the first results from the Trace Gas Orbiter," says Håkan Svedhem, TGO's project scientist. "Our instruments are performing well and, even within the first few months of observation, are providing exquisite data to a much higher level than previously achieved."

Among the findings released was the most comprehensive map ever produced of water held within Martian soil. It was constructed using data from the FREND instrument, which is able to track water-ice and hydrated minerals within the top metre of Mars's surface.

"[There] is for sure, a lot of water in the subsurface of Mars. Mars is rich in water," says Igor Mitrofanov, from the Russian Academy of Sciences and FREND's principal investigator.

The map is in its early stages, but the preliminary measurements show that the polar top soil is up to 30 per cent water. While most of the equatorial regions are dry, there are some oases, such as Valles Marineris – a valley believed to have been shaped by a long-since dried up river.

These water-rich locations could be potential search sites for evidence of past, or even extant, life on Mars. However, along with findings that fuelled the hopes of uncovering Martian life, ExoMars TGO provided others which dashed them.

"During our period of observation in 2018 we did not see any methane, down to low levels [12 parts per trillion]," says Oleg Korablev from the Russian Academy of Space Sciences and principal investigator of TGO's ACS spectrometer.

This is something of a blow, as the gas had been detected in 2013 by both Curiosity and the Mars Express orbiter. However, this detection was a localised, temporary spike, leading to theories the release was caused by seasonal melting of the permafrost, or even a bloom of bacteria. ExoMars's finding doesn't discount Curiosity's results – the orbiter would only have detected an individual spike if it was looking at it directly – but it does suggest such methane outbursts are rarer than hoped.
http://exploration.esa.int/mars

I. MITROFANOV ET AL. (2018), NASA/ESA/A. RIESS (STSCI/JHU) AND PALOMAR DIGITIZED SKY SURVEY, DEREK STORM, WWW.DEREKSTORM.COM, UNIVERSITY OF WARWICK/MARK GARLICK

▲ A telescopic view of the Large Magellanic Cloud, with (inset) one of its many star clusters

Universe's expansion causes confusion

An important cosmological measurement is cast into doubt

New results from the Hubble Space Telescope have only cast more confusion over one of the most fundamental observations of the cosmos – how fast the Universe is expanding. The rate obtained from Hubble's observations of variable stars in the Large Magellanic Cloud is nine per cent faster than previous values calculated using the cosmic background radiation.

The mismatch in results between these two methods is one of the biggest mysteries of cosmology. "This is not just two experiments disagreeing," says Adam Riess from the Johns Hopkins University, who led the Hubble study. "The other is a prediction based on the physics of the early Universe and on measurements of how fast it ought to be expanding. If these values don't agree, there becomes a strong likelihood that we're missing something in the cosmological model that connects the two eras."

Twin benefits of space travel

The results of an experiment using identical twins to investigate the long-term effects of microgravity on the body have been revealed.

In March 2015, NASA astronaut Scott Kelly began a one-year stay on the International Space Station, while his twin brother, retired astronaut Mark Kelly, remained on Earth. Both were examined extensively by doctors before, during and after the mission to assess how Scott's long stay off the planet effected his health, while Mark acted as a control subject his brother could be compared to.

▲ The study of Mark (left) and Scott Kelly showed how well the body can recover from the side effects of long-haul space travel

Scott experienced several health issues during his trip – such as weight loss, reduced cognitive abilities, DNA damage and gene expression changes. However, within a few months of arriving back on Earth he had recovered from almost all of these. The study shows the human body is resilient to the effects of long-haul spaceflight, meaning astronauts could survive the two-year round trip to Mars with few persistent side effects.
www.nasa.gov

NEWS IN BRIEF

Heavy metal planet

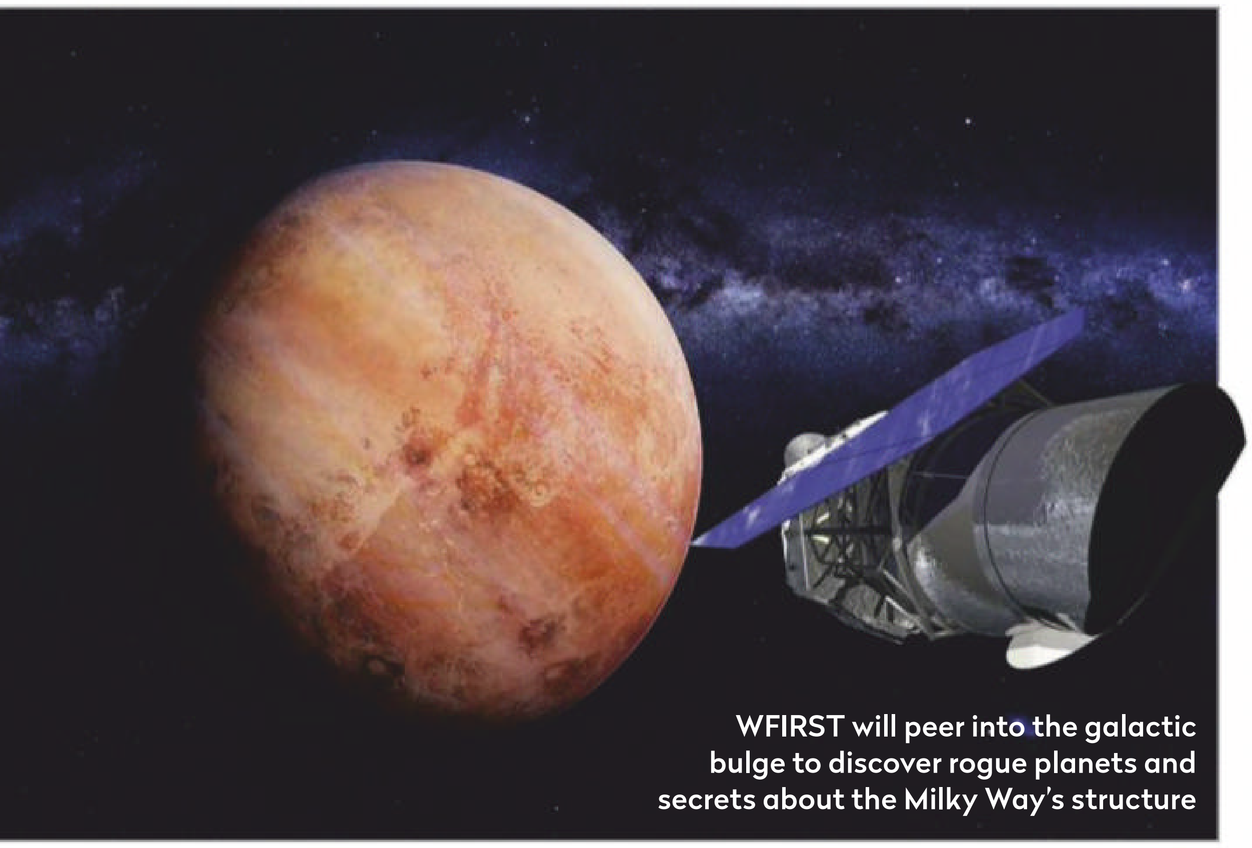
The remains of a planet composed almost entirely of metal has been found around a dead star. It's thought the world was once larger, but was torn apart when the star died. Measuring between one and a few hundred kilometres, the planetary fragment is comparable in size to the largest asteroids in our Solar System, and takes just two days to complete an orbit.

Titan wrapped in ice

An icy feature has recently been spotted wrapped around Saturn's largest moon, Titan. The ice 'corridor' encircles around 40 per cent of the moon's circumference, and does not appear to match up with any of its surface features. It's thought that the ice might be an ancient feature, which erosion is exposing.

Moon lander crashes

Israeli lunar lander Beresheet, the first non-government funded Moon mission, crashed into the Moon's surface on 11 April, following a malfunction with its engine during the descent. Despite its failure, the non-profit company behind the venture, SpaceIL, hopes to encourage others to shoot for the Moon.



WFIRST will peer into the galactic bulge to discover rogue planets and secrets about the Milky Way's structure

A telescope more versatile than Hubble

NASA's WFIRST space telescope promises great advances to astronomers in multiple fields

We looked in last month's Cutting Edge at the Wide Field Infrared Survey Telescope (WFIRST), a NASA space observatory currently under development. Part of the primary mission for which this scope has been designed is to search for large numbers of extrasolar planets using microlensing. This involves watching distant bright stars and measuring as they become distorted by the gravitational lens effect of a planetary system passing in between (as predicted by Einstein's general theory of relativity). Unlike other planet-hunting techniques, microlensing is sensitive to planets orbiting both near to and far from their star, including low mass worlds, so it will help astronomers build up a census of planetary families in our galaxy. WFIRST will also use observations of gravitational lensing events and distant supernovae to shed light on dark energy, to see whether this energy density is constant or has been changing over the history of the Universe.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster and author of *Origins: How the Earth Made Us* (geni.us/origins)

To accomplish its primary mission, WFIRST is an extremely capable scope. It has a 2.4m diameter mirror coupled with a 288-megapixel wide-field near-infrared camera and so is able to produce images as sharp as the Hubble Space Telescope, but over a field of view 100 times larger. Looking towards the galactic bulge, the telescope will monitor over 50 million stars by taking more than 40,000 images over its five-year mission. WFIRST will offer some of the deepest exposures of the sky ever taken. And this, says B Scott Gaudi at The Ohio State University, means that WFIRST will also be able to deliver even more transformational science as a by-product of its main observational mission.

Gaudi and his co-authors have written a 'White Paper' – a report of all the auxiliary science that this incredible mission could effectively give us for free. WFIRST is anticipated to detect over 50,000 microlensing events, about 500 of which are predicted to be due to isolated black holes. The scope will be effectively sensitive to objects down

WFIRST is expected to discover around 100,000 new exoplanets as they transit across their suns

to a mass of Pluto, and so will also be able to provide a survey on rogue exoplanets that are not bound to any home star. And by repeatedly imaging the brightness of its field of stars WFIRST is expected to discover around 100,000 new exoplanets as they transit across their suns, including those as small as only two Earth-radii. The space observatory will also be able to provide information on the dark outer limits of our own Solar System and is predicted to detect around 5,000 Trans-Neptunian objects, with diameters down to 10km.

But perhaps most excitingly, WFIRST has the potential to perform asteroseismology on a million or so of the stars in its field of view. Asteroseismology – the study of oscillations in stars – reveals the vital statistics of stars, such as their mass and radius, and WFIRST will be able to combine this information with precise measurements of the distances to the stars using parallax. This wealth of data will tell us an enormous amount about the stellar population in the galactic bulge and the structure of the Milky Way.

Lewis Dartnell was reading... *'Auxiliary' Science with the WFIRST Microlensing Survey* by B Scott Gaudi. **Read it online at arxiv.org/abs/1903.08986**

The golden age of galaxy growth

Investigating the conditions that made it possible for galaxies to undergo a riot of star formation

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also director of the Zooniverse project

When was the Universe's golden age? There's a strong case for the period, a few billion years or so after the Big Bang, when star formation was at its height. Galaxies would have been lit up like the sky on Bonfire Night as enormous bursts of star formation rippled across them, a spectacular show taking place just before most galaxies as large as the Milky Way settled down to a comfortable and sedate middle age.

The authors of this month's paper, led by Avishai Dekel, a professor at the Hebrew University of Jerusalem, want to know when galaxies were forming stars fastest, and when the supermassive black holes they have at their centres were growing most quickly. Their answer to both questions, derived from complex cosmological simulations, is that the golden era came 3,300 million years after the Universe began.

Armed with that knowledge, they set out to ask a simple question. Why then? It turns out it is partly a question of scale. To see why, think of a Universe filled with what cosmologists call haloes of dark matter – clumps of material, within which galaxies grow and live. Simulations tell us that these haloes merge over time, so their average mass gets larger as time progresses.

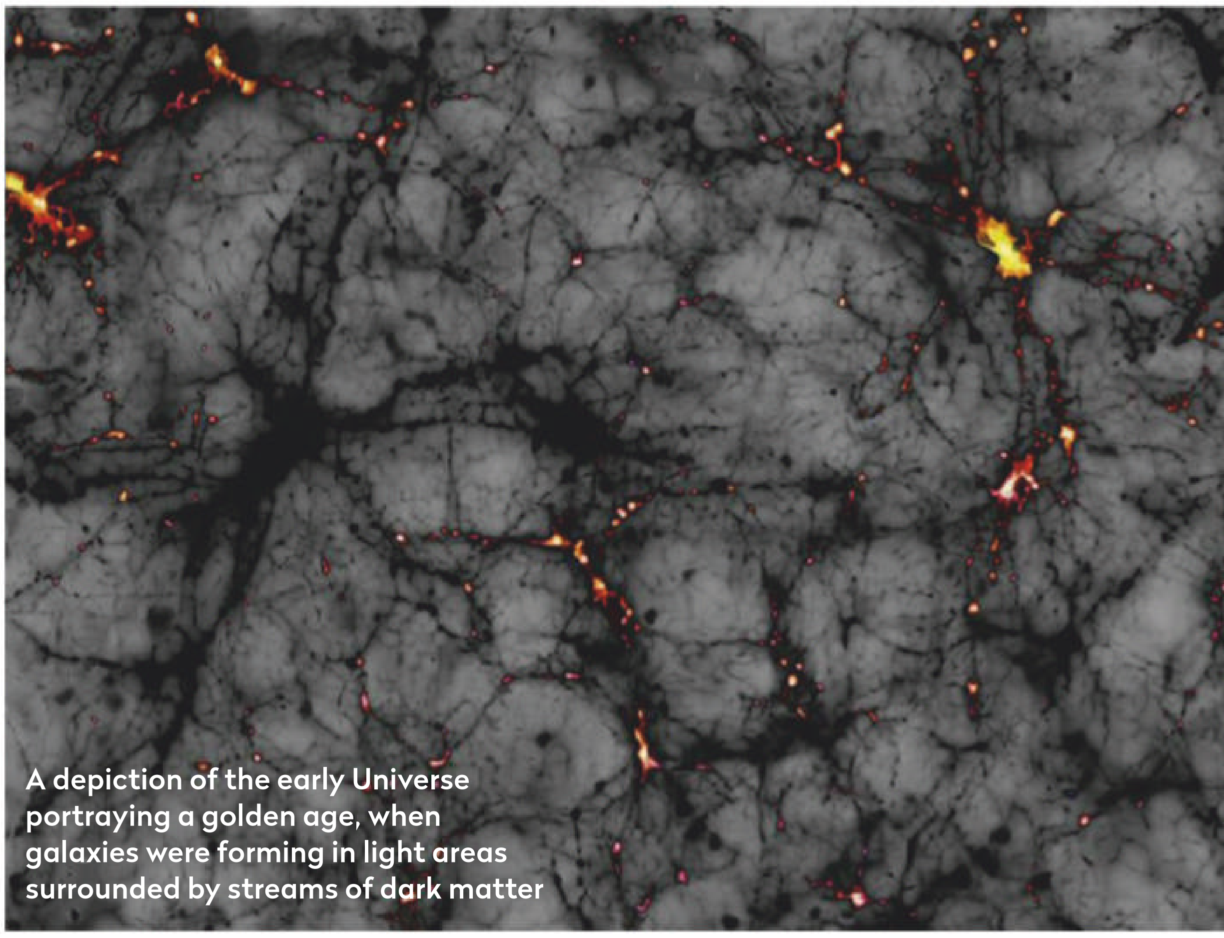
At around the 'golden age', the most common mass for such a halo is a thousand billion solar masses, and it turns out that this mass is perfect for star formation. The authors argue that when a halo gets to this sort of mass, the galaxy within it undergoes a complex series of transformations. The normal matter, under the influence of the stars which have already lived out their lives in the galaxy, compacts, forming a dense 'blue-nugget' in which stars can form, and where the black hole at the galaxy's centre has a plentiful supply of gas.

With rapid star formation underway, a galaxy in such a state will either quickly use up its gas, or otherwise stop star formation. In either case, what's left after the burst is over is first a red nugget, and then what might be a normal elliptical.

So galaxies in haloes at this particular mass may have simply behaved differently from others. Smaller haloes can't sustain star formation; even a single supernova will be powerful enough to expel gas from the galaxy completely. Meanwhile, those more massive than the critical size have a hard time getting gas into their galaxies. When gas flows into these clusters, there's enough material confined in the halo – but trapped between the galaxies – to heat it up and prevent it falling into a galaxy. Supercluster-sized haloes are likely still growing, but will be starving the galaxies at their heart.

The golden age was when the average structure in the Universe was just right to encourage star formation

So that's the answer. The golden age was the time when the average size structure in the Universe was just right to encourage star formation. Instead of being nostalgic, though, we can use all the telescopes and tools at our disposal to look back at this exciting epoch – and test the theoretical ideas presented in this paper.

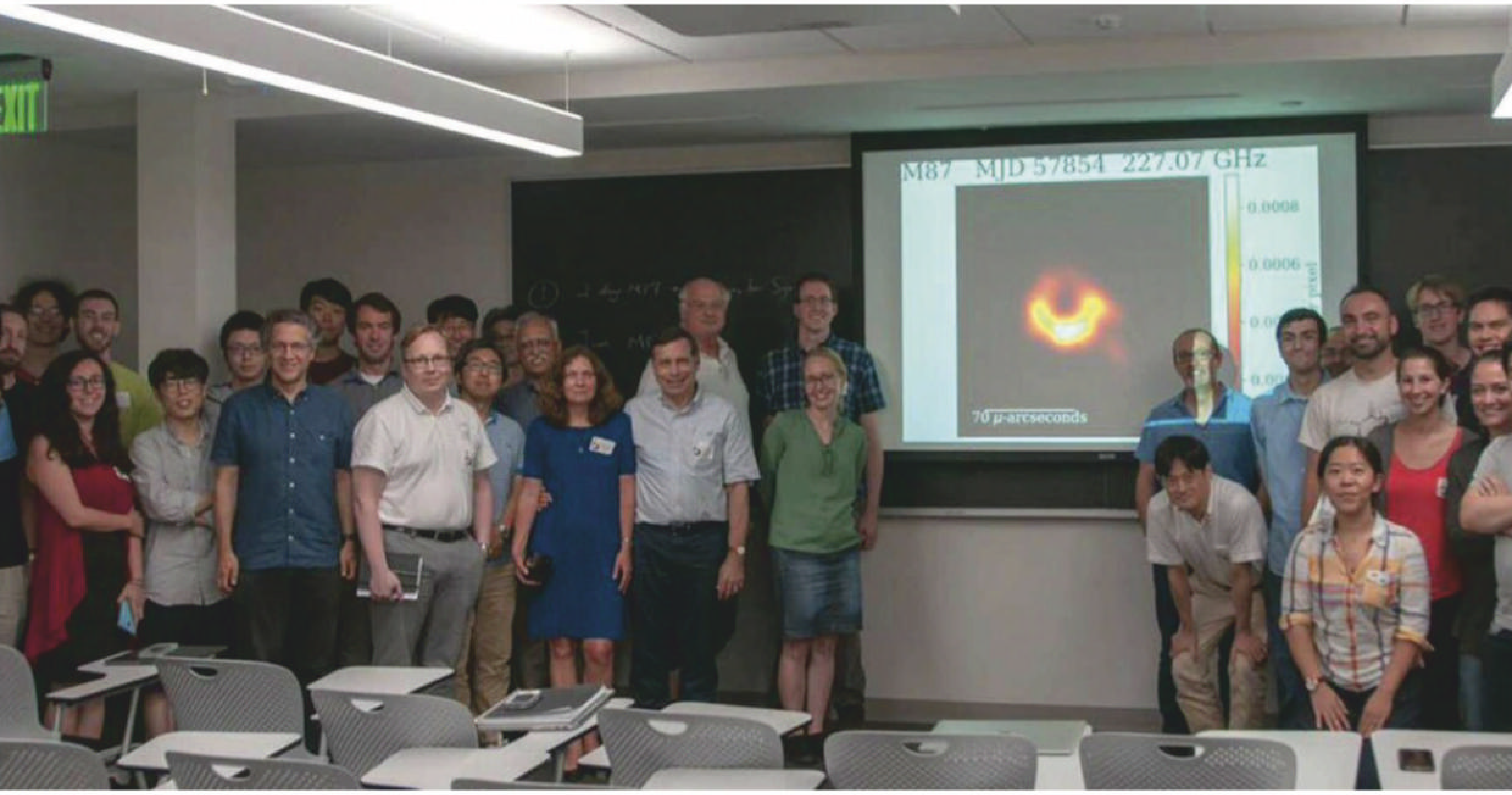


A depiction of the early Universe portraying a golden age, when galaxies were forming in light areas surrounded by streams of dark matter

Chris Lintott was reading... *Origin of the Golden Mass of Galaxies and Black Holes* by Avishai Dekel, Sharon Lapiner and Yohan Dubois. **Read it online at arxiv.org/abs/1904.08431**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ Researchers from the Event Horizon Telescope celebrate after creating the first image of a black hole

In May's *The Sky at Night* episode, the team looked at the historic first image of a supermassive black hole at the heart of galaxy M87. Astrophysicist **Ziri Younsi** is a UK contributor to the project

On 10 April 2019 the Event Horizon Telescope (EHT) collaboration presented the first direct image of a supermassive black hole to the public. Located in the heart of the galaxy M87, EHT scientists imaged the shadow cast by M87's black hole against a background of luminous material. This luminous material is heated as it falls onto the black hole and emits radio waves that we detect on Earth, with the dark centre of the image coinciding with the black hole itself.

The EHT is a collaboration involving more than 200 scientists, engineers and even philosophers from all seven continents. Producing the image we see today was a tremendous achievement, requiring the coordination of the efforts of all those involved. It was no small feat to link up eight radio telescopes from around the world to simulate a giant telescope the size of Earth.

The journey from an abstract notion to a tangible image has been more than two centuries in the making. In 1783 the Reverend John Michell, applying Newtonian theory to light, conceived the term dark star: an object with a gravitational field so powerful that not even light could escape its surface. In 1915 Einstein's revolutionary general theory of relativity predicted black holes, and in the years to come this 'surface' would become known as the event horizon, a one-way threshold beyond which neither matter nor light could ever escape. By 1967, John Archibald Wheeler had given the mysterious object lurking behind the event horizon a new name: a black hole.

By the 1970s, indirect observational evidence for the existence of black holes was compelling and research into understanding what a black hole would look like was well underway. James Bardeen and Christopher Cunningham presented the first visualisations of the black hole's shadow and in 1978, Jean-Pierre Luminet painstakingly calculated and hand-drew the first accurate picture of luminous material around a black hole.

EHT COLLABORATION, NASA/JPL, NASA

Dr Ziri Younsi is an astrophysicist at University College London (MSSL), and member of the Event Horizon Telescope

But how could we ever image a supermassive black hole like the one in M87, which is 55 million lightyears away? Heino Falcke, Fulvio Melia and Eric Agol's theoretical calculations in 1999 provided an answer. They demonstrated that by combining simultaneous radio observations from different telescopes across the globe, imaging the black hole in the heart of our Galaxy was feasible. By 2009 the Event Horizon Telescope, led by Sheperd Doeleman, set out to do just this.

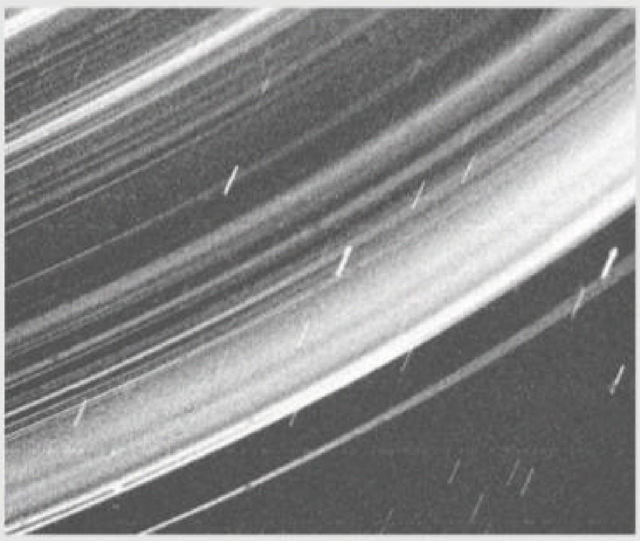
Having worked on black holes since my PhD, working with the EHT since 2014 has been an exciting experience. It has allowed me to combine my theoretical knowledge and calculations of black hole properties with the expertise of many other scientists from many different fields, involving me in a once-in-a-lifetime collaborative effort.

Einstein's general theory of relativity has been the cornerstone of 20th-century science, providing an understanding of our world that has enabled GPS systems and even predicted black holes. The image of M87's black hole is a first step towards a deeper understanding of the nature of matter and light, and towards testing the very limits of Einstein's theory to see if it holds true in the most extreme conditions in our Universe.

Looking back: The Sky at Night

June 1977

On the 15 June 1977 episode of *The Sky at Night*, Patrick Moore looked towards the outer Solar System and the planet Uranus. A few months before, on 10 March, a group of researchers from Cornell University, New York, had been studying the planet's atmosphere during an occultation – when it passes in front of a star, temporarily blocking out its light – when they made a surprising discovery. Before and after the occultation, the team noticed a series of smaller dips in the star's light, which they realised was caused by a series of thin rings around the planet. Until that point, the only known planetary ring system was the spectacular disc that surrounds Saturn, though now we know that both Jupiter and Neptune also have a system of thin rings.



▲ **The ghostly rings of Uranus as imaged by Voyager 2 from a distance of 236,000km**

The team would have to wait until 1986, when NASA's Voyager 2 flew past the planet, to get a closer look at the ring. Then in 2003 and 2005 the Hubble Space Telescope undertook a campaign to image the rings, making out 13 separate examples, with the largest measuring 100,000km in diameter.

Return to the Moon

Fifty years since humans first stepped on the Moon we are on the verge of a new golden age of lunar exploration. With American, European, Chinese, Russian, Indian and Israeli missions all targeting the lunar surface, this month *The Sky at Night* looks into the technology that will take us back to the Moon, and asks "Why do we want to go there?"

BBC Four, **9 June,** 10pm (first repeat BBC Four, **13 June,** 7.30pm)
Check www.bbc.co.uk/skyatnight for subsequent repeat times

▲ **How will we follow Gene Cernan (Apollo 17), the last human to set foot on the Moon?**

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2019 Stargazing.*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

A safe place in the Sun

▲ To locate the Sun, Mr Horrox has made a solar filter for his scope and a viewing shield for his eyes

I have found a simple and quick method of locating the Sun through my 70mm refractor and wonder if other readers would be interested trying it out. First, to make my 70mm telescope safe for viewing the Sun, I made a solar filter for its objective lens from cardboard and solar film. Then I cut a stiff piece of cardboard to about 20x30cm. Next I cut a narrow slot down the centre and glued a strip of the solar film used to construct the cap over the slot. It's then possible to align the view on the Sun by looking along the top edge of the eyepiece and lining the Sun up in the slot. By marking a spot on the cardboard next to the film when the Sun has been found, I can now locate the Sun in the eyepiece in about 5 seconds or less.

Mr C Horrox, Sale

An ingenious way of aligning on the Sun, Mr Horrox, and a great way of using up any leftover solar film! Remember to make sure you use accredited solar film. ***– Ed***

Tweets

Nigel Martin
@Nippy_Nige • Apr 13
Mesmerizing Moon. Never ceases to amaze. Captured this evening 130419 #MoonLovers #moon @EarthPix @BBCEarth @EarthandClouds2 @ planetepics @earthskyscience @EarthandClouds @NASAMoon @skyatnightmag @ BBCStargazing @ThePhotoHour

Looking for Hubble

I'm a chemical engineer who fell in love with astrophotography about two years ago. On 7–8 March I took part in a Messier Marathon at a small holy monument in Isfahan Province, Iran, about 400km southwest of Tehran. Over 150 stargazers attended this dusk to dawn competition, which is held every year before the spring equinox – to look for the Messier objects with their telescopes – and at around 4.40am the Hubble Space Telescope joined us too, passing overhead. It was amazing how NASA joined our competition.

Omid Ghadrdan, via email

The hole picture

An absolutely amazing use of technology and science to see an actual image of a black hole. Is there any risk that the algorithms used and deemed to be correct were merely conforming to produce an image to match our expectations?

Murray Foster, via email

To avoid bias there were four different algorithms, each developed in isolation, which were also fed misleading data. Each one ended up generating the same sized ring that was brighter in the south. For more on the Event Horizon's black hole image, read our feature on page 26. ***– Ed***

First scope

I had the good fortune of being able to attend Brian Cox's Universal world tour in Aberdeen recently. Despite having an interest in all things space, astronomy and science fiction from an early age I have never owned a telescope or really tried to observe the night sky for myself. Something in his presentation gave me that push to get reading *BBC Sky at Night Magazine* again for clues, hints and tips and after some extra research I settled on a scope of my own – a Celestron Powerseeker 127EQ. The weather had me stumped for several weeks, but when it relented the views of the crescent Moon made me feel like I was in orbit. At that point I knew there was something in this hobby for me if I could just persevere. Persevere I did, so imagine how great it felt to get Mars in the scope. Of course it was not much more than a muddy dot, even with a 4mm eyepiece, but it was unmistakably larger than a star and brown and red in colour. I would say to anyone on the fence about buying some optics to observe the night sky to go ahead and do it. I have to wait until 2020 for Mars's next close approach but that gives plenty of time to look at the multitude of other objects in the sky. Thank you Brian Cox!

Cameron Naismith, Fraserburgh

Two extremes

I recently returned from the US where I experienced the extremes of a dark sky and light pollution. I saw the stars over the Grand Canyon and at Bryce Canyon – which claims to have the darkest sky reachable by a paved road in the US. It was breathtaking. The airport for fyling home ▸

ON FACEBOOK

WE ASKED: What is your favourite object in the Solar System?

Alex Townsend
Saturn because it's massive and I love the bit in *Interstellar* when they are passing by it looking like a tiny spec of dust.

Andrew Murray
Comet Holmes because it briefly became the largest object in the Solar System.

Gerry Gee
The Oort Cloud – that giant swarm of icy objects, some the size of mountains, that crash into each other and produce some amazing comets.

Rebecca Stobie
Pleiades. So easy to spot, it's beautiful.

Kris Derry
Cruithne. Sometimes referred to as 'Earth's second moon' as it follows us along our orbital path around the Sun.

Martin Bailey
Pluto. Always a planet to me.

Keith Moseley
Neptune because of its lovely shade of blue, changing cloud patterns and sense of mystery.

Danny Ellis
Hyperion, because it's a mad floating sponge

Andrew Knight
Bright comets such as Hale-Bopp or Hyakutake

David J White
The ISS. There's nothing better than getting a notification from VirtualAstro saying you have a 5 minute warning before it flies overhead.

SCOPE DOCTOR

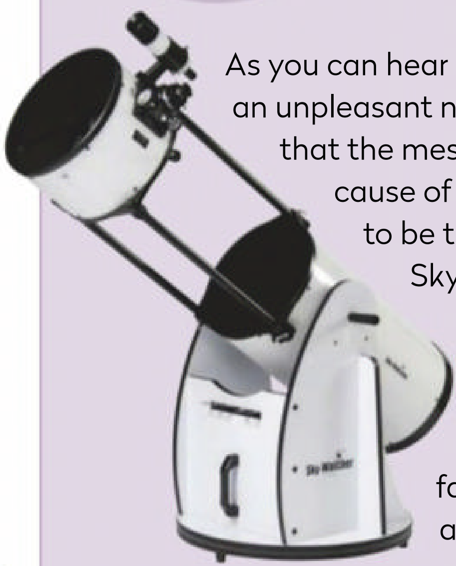
Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher Skyliner 300P FlexTube Go-To telescope. Though I can hear the motor working, the azimuth base is slipping. Taking off the base and adjusting the bolts and worm gear makes no difference. Can you help?

MARTIN FOAD



▲ **The Skyliner 300P FlexTube has an easily adjustable slip clutch**

As you can hear the motor working yet not making an unpleasant noise, it would be safe to assume that the meshing of the worm gear is not the cause of the slippage here. It's more likely to be the slip clutch. Both axes on the Skyliner 300P FlexTube Go-To mount have this slip clutch for safety, to protect the gears from damage in case the movement of the scope is impeded in any way. It's fairly basic in operation but can be adjusted if it does start to slip too easily. To adjust the clutch on the azimuth axis, remove the four crosshead screws that keep the plastic cover in place on the rocker box base. This will reveal the exposed motor and encoder, which is a circular black housing. If you look under the encoder housing, you will see three 'washers' and a 17mm AF self-locking hexagonal bolt. Gently turn this bolt clockwise to tighten the clutch – just an eighth of a turn should suffice.

Steve's top tip

What is collimation?

Collimation describes how accurately the optical elements in a telescope are aligned with one another and to the optical tube that contains them. Irrespective of whether the telescope is a refractor or reflector, it is necessary for all the optical elements to be accurately aligned to achieve the best views or images from the scope's design. A badly collimated telescope will display poor star shapes and other aberrations that will spoil the view. It is also important that the optical elements are aligned with the tube assembly, otherwise there can be problems with aligning the focuser, which is a purely mechanical part of the instrument.

Steve Richards is a keen astro imager and an astronomy equipment expert

PAUL WHITFIELD

BBC Sky at Night MAGAZINE

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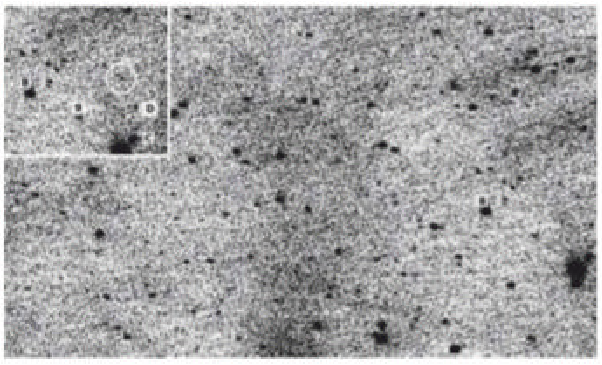
Tweets

Pete Collins
@diamondskies99 • Apr 25
Stars that never set – circumpolar constellations from Twistleton Scar, #YorkshireDales @yorkshire_dales @StormHour @BBCEarth @BBCStargazing @uknationalparks @skyatnightmag

▸ happened to be Las Vegas and, thanks to your April edition, I realised I was there for Earth Hour. I could not have been in a worse place. There are places there where the night sky has been cut off from view, enclosed by domes that give the impression of daylight.

Peter Shirley MBE FRES, West Bromwich



Technical challenge

One of my favourite parts of the magazine is the gallery of talented readers' images. However, it's rare to see images which aren't so immediately attractive but which are technically challenging or scientifically valuable, or both, for instance a supernova in a far galaxy, a near-Earth asteroid making a close pass, or a gravitationally lensed cluster of galaxies. To encourage others, here is one of mine. It shows Sycorax, a satellite of Uranus, which was discovered in September 1997 by the 5.1m Hale Telescope at Palomar Observatory.

I took this with a telescope with only 8 per cent of its aperture, or 0.64 per cent of the light-gathering power. These objects are rarely observed by professionals and yet their position on the sky can be measured precisely, to well under an arcsecond, which allows their orbits to be determined to greater accuracy.

Paul Leyland, via email

SOCIETY IN FOCUS

High Legh Community Observatory (HLCO) operates from a small plot of farmland in the Cheshire countryside, run by volunteers and led by chairman Mark Holmes and secretary John Anderson (pictured). We have monthly meetings with guest speakers covering a wide range of topics. In March, 57 people attended a talk on the mysteries of dark matter by Dr Steve Barrett from the University of Liverpool.

HLCO is open to the public every Friday from dusk, and our most recent event had a good attendance of adults and children. The sky was clear and the seeing fairly good. We used our main telescope, a Meade 300mm Schmidt-Cassegrain with GPS and Go-To capability, to observe the Great Orion Nebula, M42, the reddish gaseous nebula below Orion's Belt. We also had a star-hopping session for those who had no prior knowledge of the night sky – and introduced Orion, Taurus, Gemini, Leo and, of course, the Plough and the Pole Star.

When we lowered the scope southwest towards Mars, the Red Planet's disc was clear, along with an indication of the polar ice cap, before we moved on to the open cluster, M35 and Double Cluster in Perseus. The attendees were then shown how Castor (in Gemini) and Mizar (in the handle of the Plough) were revealed as double stars when viewed through a telescope. It was a very enjoyable night observing at HLCO.

www.highlegh-communityobservatory.com

Rebecca Holmes, steering group, HLCO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Our pick of the best events from around the UK

WHAT'S ON

Summer solstice session

Brecon Beacons National Park Visitor Centre, Libanus, Brecon, 22 June, 10am

Celebrate the summer solstice in one of Wales's beautiful National Parks. Experienced astronomers will be on hand to enthral you with all things solar.

cardiff-astronomical-society.co.uk

Charles Piazzi Smyth 200

Nelson Monument museum, Edinburgh, throughout June

This exhibition marks the bicentenary of the birth of Astronomer Royal for Scotland Charles Piazzi Smyth, whose work changed the way we view the night sky. Entry is free.

www.edinburghmuseums.org.uk

Glasgow Science Festival

Glasgow, 6-16 June

The festival includes a look at space mission design via the French language, after-hours planetarium shows and more.

www.glasgowsciencefestival.org.uk

See the Sun on Scilly

Community Observatory, St Martin's, Isles of Scilly, 7, 14, 21, 28 June, 2pm

Join amateur astronomers COSMOS at their observatory for solar observing. It's £5 for adults and £3 for under-16s.

www.cosmosscilly.co.uk

PICK OF THE MONTH

▲ There'll be all sorts of ways to engage with science in Cheltenham this year

Cheltenham Science Festival

Cheltenham, 4–9 June

This year's festival is one of many across the UK marking the 50th anniversary of the Apollo 11 Moon landing, making it a must for fans of spaceflight. Rick Armstrong, son of astronaut Neil, will be attending to reminisce on the excitement of 1969 and join a panel of space scientists looking towards future missions.

Helen Sharman, the first Briton in space, shares her experiences on the MIR Space Station in 1991; author and presenter Dallas Campbell blends science and music in 'The Bach Side of the Moon'; and *The Sky at Night*'s Chris Lintott joins musician Steve Pretty for a collaboration between astronomy and jazz.

This year also marks the centenary of UK astronomers Arthur Eddington and Frank Dyson's 1919 eclipse expedition, which put Einstein's General Theory of Relativity to the test. Their groundbreaking journey and observations will be remembered in a special event during the festival.

For the full listings and to book tickets, visit the festival website.

www.cheltenhamfestivals.com/science

Astrophotography for beginners

Emberton Sports and Social Club, Emberton, 15 June, 7pm

UK Astronomy hosts an introduction to astrophotography for those who want to image the night sky as well as observe it. Entry is £3, or £10 for groups of four.

www.ukastronomy.org

Apollo 11 celebrations

Wells & Mendip Museum, 22 June 2019, 10am

Join Wells and Mendip Astronomers for an event marking the 50th anniversary of Apollo 11, including interactive displays, lunar photography, virtual reality and the chance to handle moonrocks. Entry is free.

www.wellsastronomers.org.uk

Macclesfield solar observing

Tegg's Nose Country Park Visitor Centre, Macclesfield, 22, 23 June, 12pm

Tegg's Nose Rangers and Macclesfield Astronomical Society host a day of observing our closest star, with members on hand for discussion. Tickets are £5.

https://bit.ly/2IOhnSA

CARDIFF ASTRONOMICAL SOCIETY, CHELTENHAM SCIENCE FESTIVAL X 4

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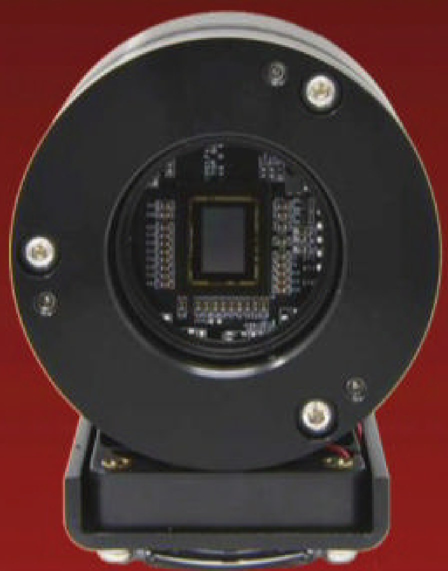
CMOS technology is moving ahead at a fast rate. With Quantum Efficiencies (QEs) starting to rival those of traditional CCDs, along with low read-noise figures, some slightly below that of our CCD cameras, CMOS is starting to become a viable alternative.

For fast planetary imaging, CMOS is now the dominant sensor, however, it does suffer from amplifier glow which is inherent in all CMOS sensors and is a problem for deep-sky imaging. Many users stack thousands of short images together to achieve a longer exposure time, and this method is useful to help reduce tracking and seeing errors, however, it limits the signal to noise ratio for each frame and is not as good as adding several long exposure frames together. In both cases, it is critical to ensure that you have good calibration frames to help with the removal of amplifier glow. It can also require a lot of processing power and disk space when manipulating hundreds or thousands of stacked images together.

It has always been virtually impossible to eliminate amplifier glow without post-processing techniques, which means manipulating the raw data, often before it arrives at the computer. The engineers at Starlight Xpress were not about to be beaten! After working for a few months, experimenting with various clocking routines we have developed a methodology that will allow you to take up to 15 minute exposures with minimal glow, while maintaining your raw data. We call this our ''No Glow Technology"; (Even Sony have asked us how we do it!)

As with all of our TRIUS range of cameras, we have incorporated a USB hub into the main camera, which offers 3 x USB 2.0 ports at the rear of the camera. Each port is capable of delivering up to 200mA, and is able to drive a Lodestar, or UltraStar for guiding and another two USB ports for our USB filter wheels etc. This integration greatly reduces the number of cable trails back to the computer and gives less potential cable tangling around the mount during your imaging session.

New 3 stage Peltier cooler combinations have been designed into the CMOS TRIUS cameras, along with the Argon-filled sensor chamber for delivering good cooling to the CMOS sensors.



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CSX-304	IMX304	12.3M	14.13 x 10.35	4096 x 3000 (3.45um x 3.45um)	3e-	75mm x 70mm	62%	1lb	>11K	12 bit
CSX-249	IMX249	2.3M	11.52 x 7.2	1920 x 1200 (6um x 6um)	3e-	75mm x 70mm	80%	1lb	>33K	12 bit
CSX-290	IMX290	2.13M	5.61x 3.175	1945 x 1097 (2.9um x 2.9um)	3e-	75mm x 70mm	80%	1lb	>15K	12 bit

 # Typical read-noise values at Unity Gain. These values are reduced to approx 1.5 e- as gain is increased

FIELD OF VIEW

Ship-shape and stargazing

Many of today's cruiseships set sail with a resident astronomer as part of the crew. We join **John Maclean** for a deck-side view of the night sky

ALEX GREEN/FOLIO ART

John Maclean is a resident astronomer on cruise ships for Viking, Cunard, P&O and SAGA

At 10:30pm in the evening on a cruise ship sailing serenely across the Bay of Bengal, around 150 guests are gathered on the upper deck. Suddenly, a green laser shoots into the night sky and immediately the night is filled with gasps of wonder as the crowd follows the beam as it appears to pull its target object down from the sky to deck level. The object being observed is the planet Mars, and many of those in attendance have never observed a planet, let alone from the deck of a ship.

Astronomy at sea is not a new phenomenon – Sir Patrick Moore himself observed the Solar Eclipse from the deck of the *Monte Umbe* off the coast of Mauritania in 1973 and went on to lecture on the first astronomy cruises started by American Ted Pedas, who had 'invented' these themed cruises under the banner of 'Science and Culture at Sea'.

I first started lecturing and operating planetariums on the flagship of the Cunard line, *Queen Mary 2*, back in 2013. *Queen Mary 2* was the first ship to have a full size planetarium on board and since it was launched, Fellows of the Royal Astronomical Society have acted as resident astronomers and deliver talks on astronomy, cosmology and astrophysics to interested guests.

Now, more cruise lines are installing planetariums on their ships and embracing astronomy and space exploration as a theme; some cruise lines have special 'Space Week' cruises in October each year. Generally, when I am on a ship as resident astronomer I will be expected to give talks on 'sea days' and if the ship has a planetarium, deliver some 'What's in the night sky?' shows. I'm usually expected to run stargazing nights on the top deck and, helpfully, the captain will turn off the lights to enable better views of the night sky. Sometimes I'll do Q&A sessions, which always generate some terrific and insightful questions such as "How big is the Universe?" and "How are stars formed?"

Some of the ships I sail on even have their own telescopes. This can vary from a standard 10-inch Dobsonian to a state of the art Sky-Watcher Go-To mount with a 160mm refractor. How can you possibly use a telescope at sea, I hear you ask. Well, at sea it is difficult, but possible, and the telescopes are usually used on the top deck on 'port days' so stability isn't an issue and I have shown guests some great views of planets, nebulae and star clusters from the upper decks. Introducing guests to the night sky is a rewarding feeling but can also be hilarious. Recently, on a ship in the Red Sea I was hosting a stargazing night. We had observed planets, the Summer Triangle and Scorpious when a guest asked me, "What is that bright star on the horizon?" I answered, diplomatically, "That, madam, is an oil rig." As they say, it's a hard job, but somebody has to do it.


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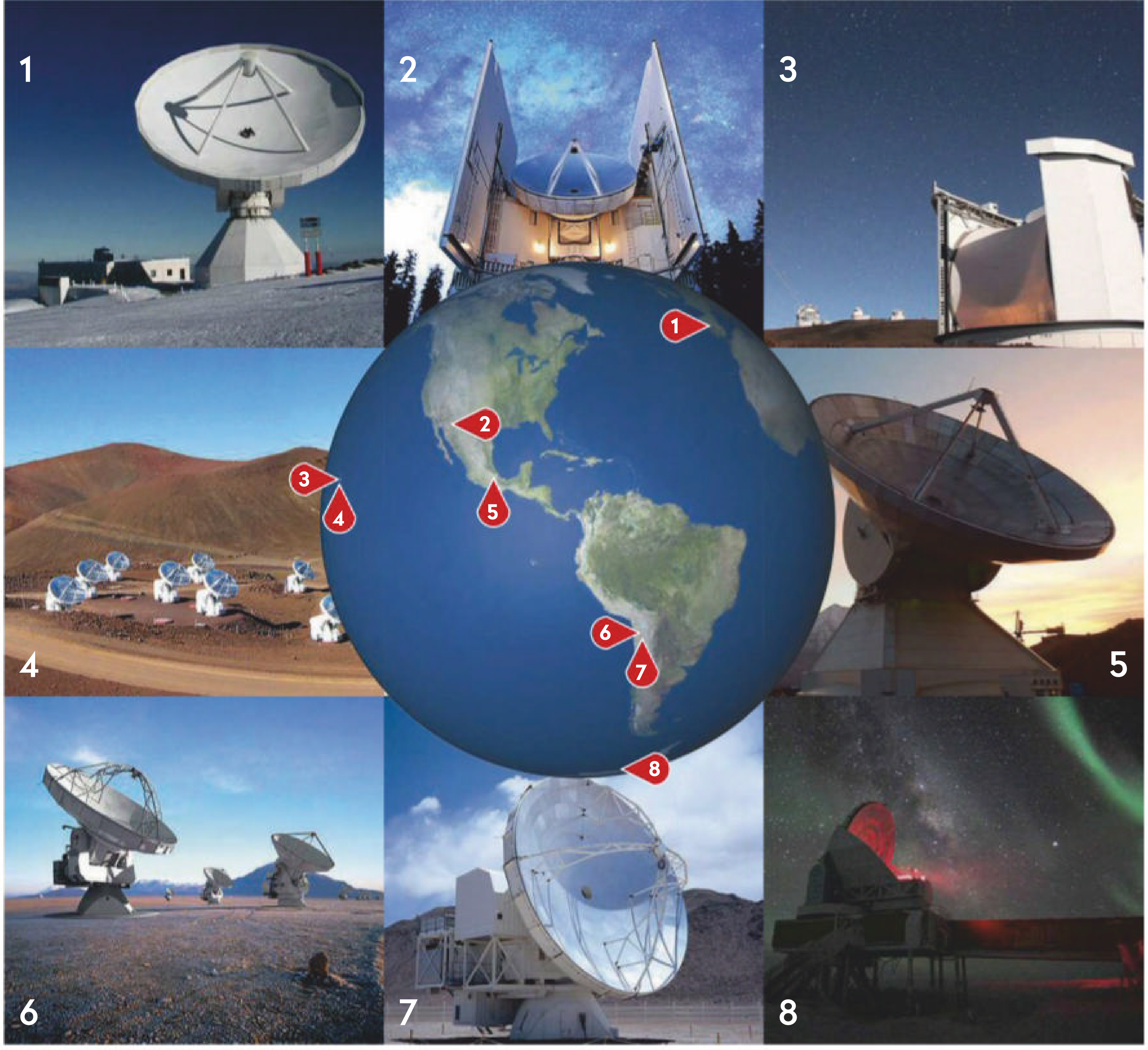
Observational data collected by a global phalanx of telescopes was combined to give humanity its first look at a black hole

Up close to a MONSTER

On 10 April the world got its first ever glimpse of a black hole. **Govert Schilling** looks at what it took to capture the historic image

Seeing is believing, they say. And although few astronomers doubted the existence of black holes, the first ever image of one of these gluttonous cosmic monsters finally constitutes the long-awaited definitive proof that they're real. Minutes after being presented at six simultaneous press conferences around the globe on 10 April, the image went viral on the internet. Within a day, it had found its way on to the front page of almost every newspaper. And for good reason, according to Nobel laureate Brian Schmidt of the Australian National University: "This image heralds a new era in astronomy."

Just over a century after Albert Einstein's theory of general relativity predicted the existence of black holes, we have finally captured one on camera, thanks to the dedication, perseverance and collaboration of scientists all over the world. According to Shep Doeleman of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts: "We've seen what we thought was unseeable." European Union research commissioner Carlos Moedas calls it "a huge breakthrough for humanity". And Heino Falcke of Radboud University in the Netherlands likens it to "...looking at the gates of hell and seeing the end of space and time".



▸ The Event Horizon Telescope created an Earth-sized virtual dish by linking up eight radio telescopes around the world

1 IRAM 30m Telescope, Spain
2 Submillimeter Telescope, Arizona
3 James Clerk Maxwell Telescope, Hawaii
4 Submillimeter Array, Hawaii
5 Large Millimeter Telescope, Mexico
6 ALMA, Chile
7 APEX, Chile
8 South Pole Telescope, Antarctica

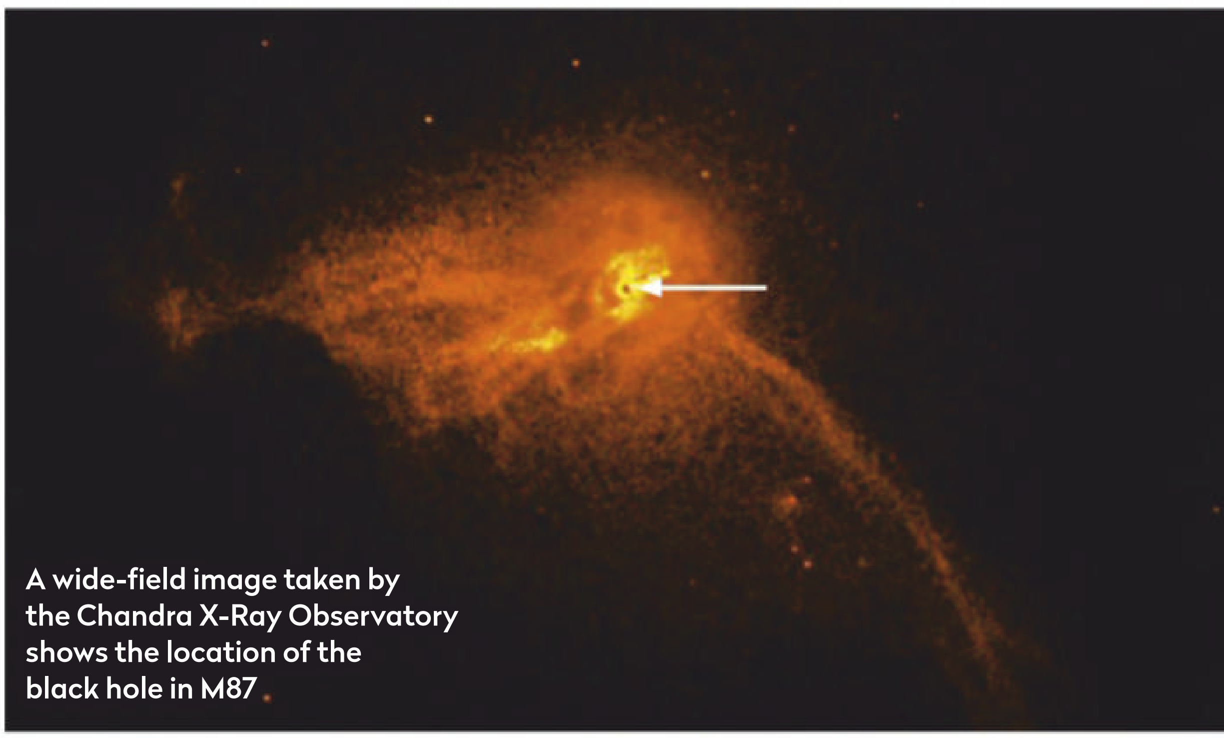
The eerie image portrays the supermassive black hole at the centre of the elliptical galaxy M87, 55 million lightyears away in the constellation of Virgo. Captured at a short radio wavelength of about one millimetre, it reveals a luminous ring of light surrounding an almost circular black blob. But this is not the actual black hole surrounded by its accretion disc of infalling gas. Instead, it's the hole's 'shadow', outlined by radiation that has been strongly bent by its fierce gravity and the accompanying curvature of spacetime. This 'photon ring' shows up no matter which direction the black hole is observed from.

The precise shape of the shadow, the size of the photon ring and even the ring's brightness distribution are all in almost-perfect agreement with the predictions of general relativity. "I was stunned that it matched so closely," says Avery Broderick of the Perimeter Institute and the University of Waterloo in Canada. From the physical size of the ring (some 100 billion kilometres), astronomers deduced the mass of the black hole: a whopping 6.5 billion times the mass of our Sun. The bright lower edge is due to an effect known as Doppler boosting, which occurs when matter is moving toward the observer at almost the speed of light.

Earth-sized dish

So how was this impressive feat accomplished? At a distance of 55 million lightyears, 100 billion kilometres corresponds to a mere 40 microarcseconds – a vanishingly small portion of sky on which to have to focus. To achieve this incredible resolution, the Event Horizon Telescope project, spearheaded by Falcke and Doeleman, linked together eight millimetre-wave radio observatories at six remote locations across the world to create a virtual dish as large as Earth. After years of preparation and technical updates (all telescopes had to be equipped with atomic clocks and fast data recorders) the observations were finally carried out over a period of four days in April 2017.

The data was then physically transported on hard disks to dedicated supercomputer centres in the US and Germany to be 'correlated', or combined, using a technique known as very-long-baseline interferometry (VLBI). Because of the sheer volume of data (five petabytes in total), online transfer wasn't possible. In the case of the South Pole Telescope, scientists even had to wait for months until the southern winter was over and flights from the pole could resume. Finally, smart algorithms turned ▸



A wide-field image taken by the Chandra X-Ray Observatory shows the location of the black hole in M87

An artist's impression of the black hole at the centre of Messier 87

▸ everything into the image that a real planet-wide radio dish would have seen. It was a Herculean task, according to National Science Foundation director France Córdova, carried out by 200 scientists from 16 institutes in more than 20 countries.

Next steps

Sera Markoff of the University of Amsterdam, in the Netherlands, describes black holes as "the major disruptors of cosmic order on the largest scales in the Universe". Indeed, even though the Solar System-sized monster black hole in M87 is just 100 millionth the size of its host, it produces powerful jets of magnetised plasma that wreak havoc throughout its home galaxy. Markoff hopes that future observations at an even higher spatial resolution will shed light on the origin of these jets.

Astronomers aren't the only scientists asking for further investigation; physicists want to see whether the black hole can show us if, and where, general relativity breaks down, or at least requires some adaptation. "We know there must be something more," explains Broderick, because general relativity doesn't happily correlate with quantum physics. "Black holes are one of the places to look for answers." So far, however, Einstein's century-old theory is again passing with flying colours. Quite ironic, given the fact that the great physicist believed that black holes were merely a mathematical curiosity without any physical significance.

The latest Event Horizon Telescope observing campaign was due to begin in late March this year, but had to be cancelled due to technical issues. Astronomers hope to try again in 2020, using additional millimetre-wave telescopes in Greenland and France. Looking further ahead, Falcke is raising funds for an African Millimeter Telescope in Namibia, to greatly improve the VLBI capabilities of the network. And both he and Doeleman are dreaming of putting instruments in space. Says Doeleman: "This image is just the beginning."

Govert Schilling is the author of *Ripples in Spacetime: Einstein, Gravitational Waves and the Future of Astronomy*

ESO/M. KORNMESSER, S. ISSAOUN/M. MOSCIBRODZKA/RADBOUD UNIVERSITY/M. D. JOHNSON/CFA

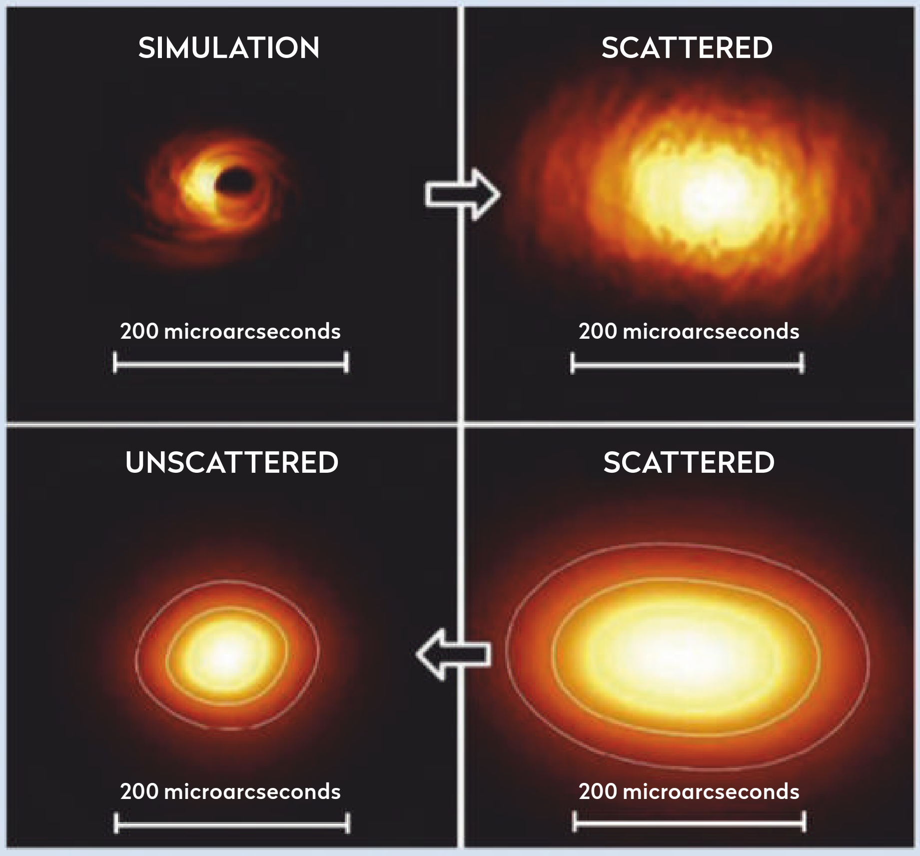
In a galaxy far, far away…

Why we had to look so far afield to see a black hole, when there's one at the centre of the Milky Way

Why go to so much trouble to image a black hole in a galaxy 55 million lightyears away when there's a supermassive one right here in the Milky Way, in our own cosmic backyard? Indeed, Sagittarius A*, as the black hole at the centre of our galaxy is officially known, is just 26,000 lightyears away. But it's also much skinnier, weighing in at a 'mere' 4 million solar masses, compared to 6.5 billion solar masses for the black hole in M87.

In fact, during the 2017 Event Horizon Telescope observing campaign, both black holes were observed and it wasn't immediately clear which one would yield the best results. Although the size of Sagittarius A*'s event horizon and photon ring should appear a bit larger (it may be some 1,500 times less massive but it's 2,000 times closer), the M87 observations soon turned out to be more promising, so the team decided to focus on that black hole.

Two other factors made observing Sagittarius A* a more complicated proposition: the intervening gas and dust in the central plane of the Milky Way, and the much more rapid variability of the source. But the observation data is in and the analysis is ongoing, so there may be more images to come.



▲ Top: a simulation of Sgr A* (left) and how it looks after the Milky Way's dust has scattered its light (right). Above: how we see Sgr A* in the sky (right) and how it looks without the scattering effect (left)

GLAMPING WITH THE STARS

Here's a great selection of places to stay where you can relax in comfort and enjoy the experience of a dark sky above

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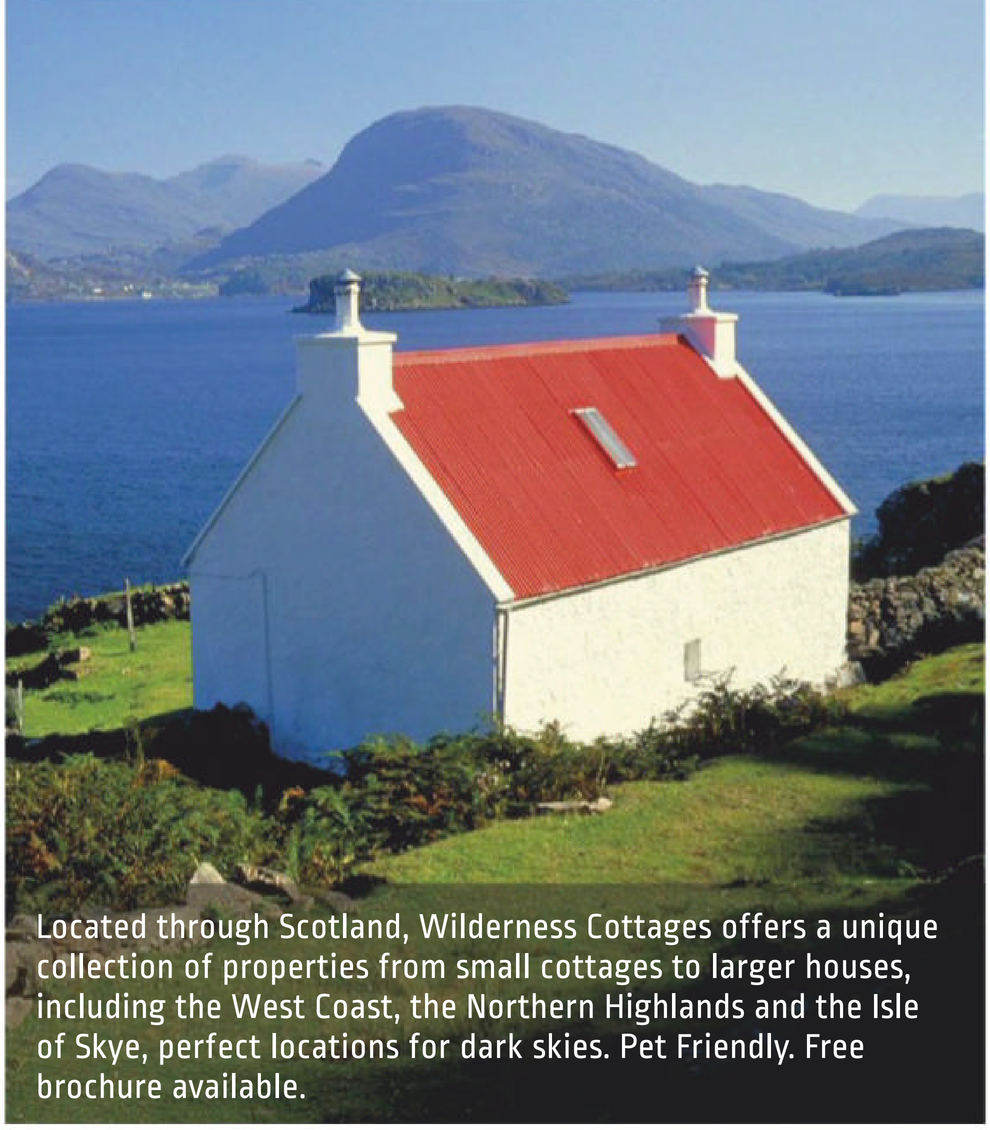

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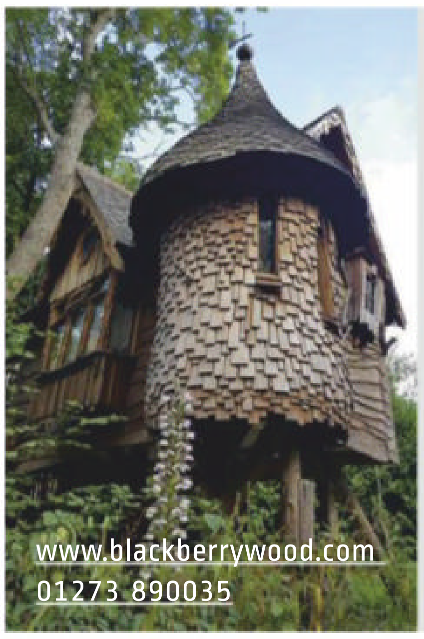

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We may have flown past all the planets in our Solar System but there are so many mysteries to still uncover

The family of the Sun

Ahead of the new BBC TV series, *The Planets*, **Elizabeth Pearson** meets our solar neighbours

DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY, BBC STUDIOS

Our Solar System began from chaos. The Sun collapsed out of a cloud of gas, drawing in a disc of dust and debris around it – the protoplanetary disc. As it cooled, heavy elements began to condense and clump together. Over time, these stuck together, growing into boulders, then to asteroids before eventually forming the eight major planets of our Solar System. Over the following 4.5 billion years, the planets have been bombarded by space rocks, gone through enormous changes in climate and been resurfaced by volcanism.

In his new BBC Two series, Brian Cox will explore not just the history of our Solar System, but how we've come to understand it now that humans have sent spacecraft to every planet and completed an 'initial survey'. Here, we take a look at what mysteries still lie among the many worlds that make up our solar family. ▸

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

Exploring The Planets

Brian Cox reveals highlights from his BBC Two series *The Planets* and discusses the future challenges of Solar System exploration

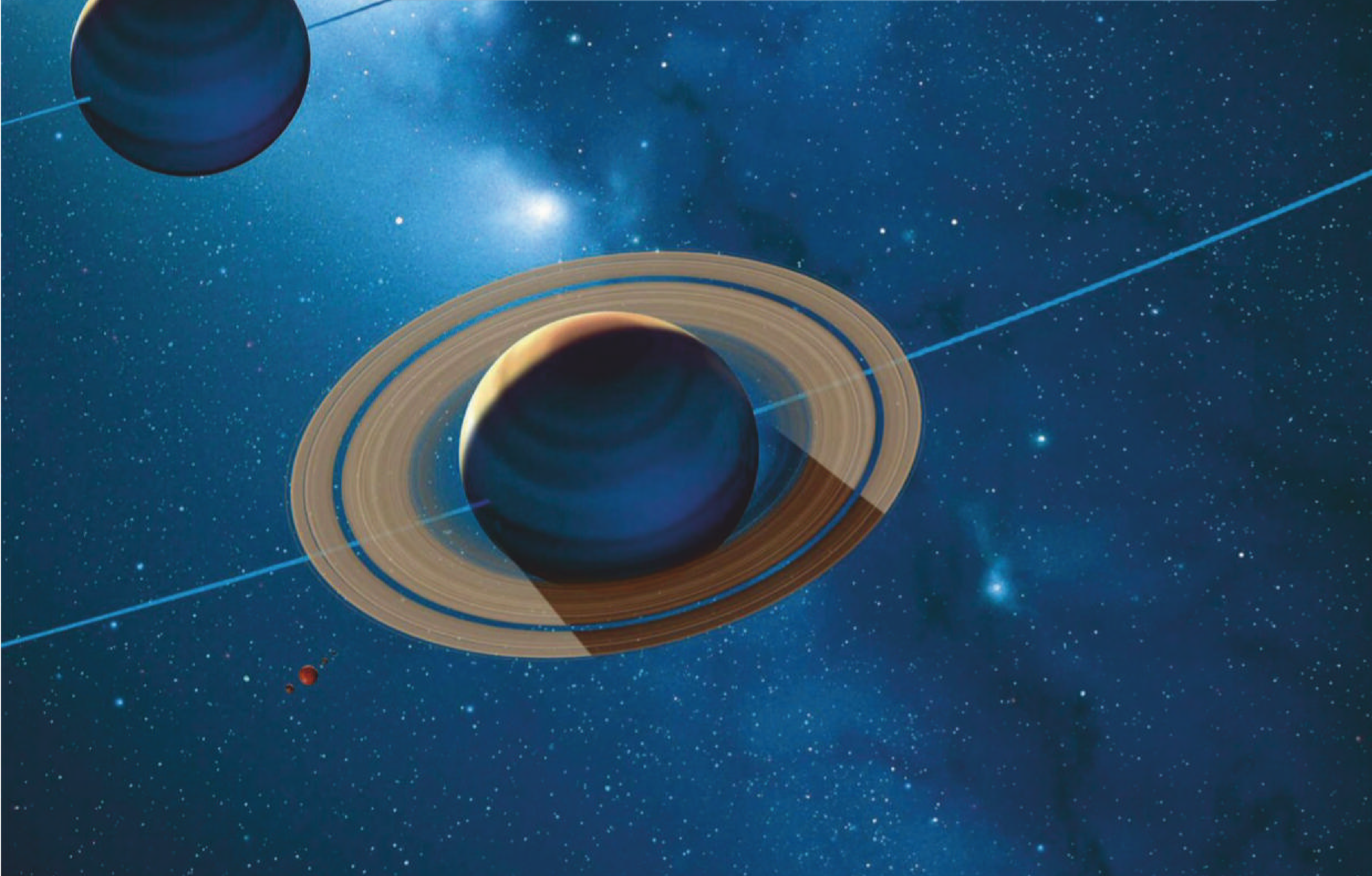
We tend to think of our Solar System as a sort of fossilised remnant, but it was dynamic and planets were moving about a lot in the early years. What's been remarkable over the past decade is the amount of detail we've been able to put into the story of the Solar System, mainly driven by planetary exploration.

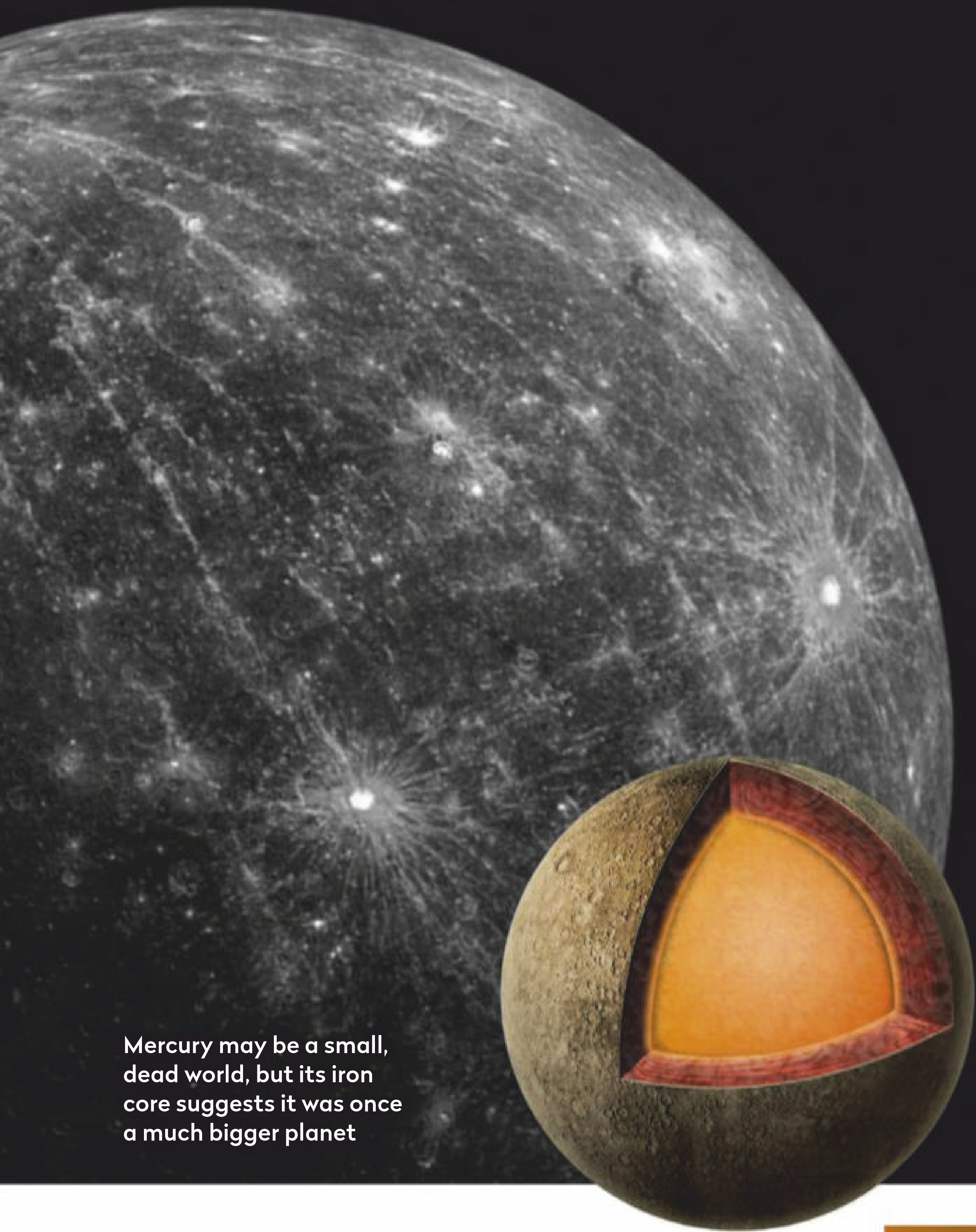
When we were making *Wonders of the Solar System*, which aired in 2010, Cassini had only just arrived at Saturn. In this new series we explore ideas like the Grand Tack model, which is a very recent development; another is that Mercury almost certainly formed farther from the Sun. We've now seen well over 3,000 planets around distant stars and know the layout of other systems is not like our own.

There's an underlying philosophy to the series, that the Solar System is a 'system'. I think it's quite natural for us to think we're isolated from the rest of the Universe, but understanding the way Mars and Venus have evolved, that atmospheres of planets can change, teaches us we as a species are fortunate, but in a rather precarious position.

Some of the biggest questions are in astrobiology, which we deal with in this series. It's that question: 'Is there life?' Particularly on Mars or some of the icy moons. That's what NASA's upcoming Europa Clipper mission is designed to look at on Jupiter's moon Europa. In one episode we focus on Titan, which is a planetary sized moon with a thick atmosphere and complex organic chemistry. There's a plan to put a helicopter drone onto it.

We've completed the initial reconnaissance of the Solar System, but only flown past Uranus, Neptune and Pluto. I'd like to see an orbiter around Neptune in particular, although it's difficult to do.





Mercury may be a small, dead world, but its iron core suggests it was once a much bigger planet

Mercury

PLANET TYPE: Rocky

The closest planet to the Sun is a desolate world. Mercury has almost no atmosphere, meaning there is no protection stopping the Sun's intense radiation baking the surface. With no active volcanism renewing the rock, the planet is now covered in impact craters, leaving no doubt that Mercury is a dead world.

At 4,880km in diameter, it's the smallest of the major planets – even the moons Ganymede and Titan are larger – but Mercury hides a heavy secret in its heart. While most planets have a modest iron core at their centre, Mercury's is thought to be enormous, spanning 85 per cent of its radius. The planet was probably much larger in the past, but lost a vast amount of its outer rocky layers. The question is how. Did a younger, much hotter Sun vaporise the rock away shortly after Mercury formed, leaving only a thin shell behind? Or did another infant planet collide with Mercury in the chaotic early days of the Solar System, stripping away its outer layers leaving only the core behind?

EXPLORED BY: Mariner 10 (1974–75); Messenger (2011–15)
NUMBER OF SPACECRAFT: 2

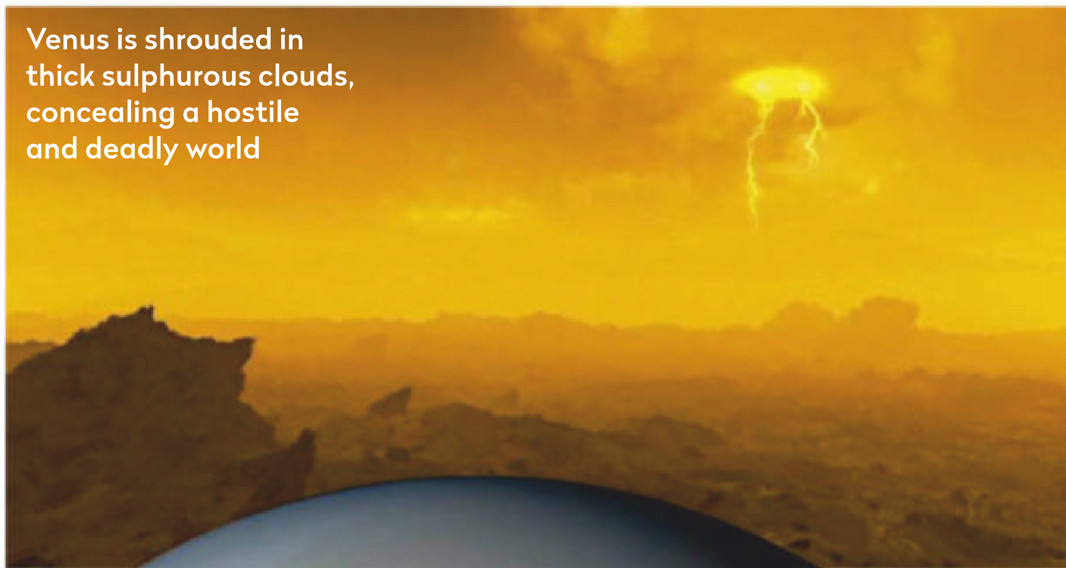
Venus

PLANET TYPE: Rocky

In many ways, Venus and Earth are very similar. They are almost identical in size and mass, and are relatively close in their distance from the Sun. But in reality, the worlds could not be more different.

Venus is shrouded from view by thick clouds of sulphuric acid, which float in an atmosphere so thick the surface pressure is 92 times what it is on Earth. Temperatures reach over 460°C – hot enough to melt lead – as the planet is in the grip of a runaway greenhouse effect. Venus was once highly volcanic, and this pumped out vast amounts of carbon dioxide. On Earth, plate tectonics recycle the carbon from eruptions back into the rock, but Venus doesn't have any tectonics. Instead, carbon dioxide levels rose until the compound made up 95 per cent of the atmosphere. This acts like an insulating blanket, trapping the Sun's heat. As the temperature rose, what water there was on Venus evaporated, forming a thick layer of swirling clouds that trapped even more heat, contributing to the creation of the planet's inhospitable conditions.

EXPLORED BY: the Mariner programme (1962–67); the Venera programme (1966–86); Pioneer Venus (1978); Magellan (1990); Venus Express (2006); Akatsuki (2015)
NUMBER OF SPACECRAFT: 24



Venus is shrouded in thick sulphurous clouds, concealing a hostile and deadly world

ISTOCK, NICOLE RAGER FULLER/NATIONAL SCIENCE FOUNDATION, SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO, IGOR FILONENKO/ALAMY STOCK PHOTO, NOAO, ISTOCK, NASA/JPL-CALTECH

Earth

PLANET TYPE: Rocky

Our home planet is unique in the Solar System: liquid water covers 70 per cent of its surface. Its presence means Earth has access to a huge array of processes that can't happen on other planets. Geologically, water acts as a lubricant between Earth's tectonic plates, keeping them moving; as well as allowing the formation of minerals that otherwise might not exist such as hematite.

Most importantly, water is vital for life. As we search for life throughout the Solar System and beyond, the mantra is always 'follow the water'.

We still don't know, however, why Earth has so much water: current theories of planet formation suggest early Earth should have been so hot that all its water boiled away. The leading explanations are that Earth managed to retain water in its core, that later bubbled to the surface, or that water was brought back to Earth after it had formed, possibly by asteroids impacting the surface.

▲ One theory for Earth's high water volume is the unlocking of underground reserves by asteroid impacts early in the planet's life cycle

EXPLORED BY: Sputnik 1 (1957); Explorer 1 (1958); Landsat programme (1972–2013); European Remote-Sensing Satellite (1991–2011); TERRA (1999); Envisat (2002)
NUMBER OF SPACECRAFT: 600+ (currently)

Canyon Valles Marineris is a tell-tale sign of the Red Planet's watery past

Mars

PLANET TYPE: Rocky

We know water once flowed on Mars – orbital images reveal the valleys formed by rivers, while surface experiments have found minerals which probably required liquid water to form.

Today, however, the rivers are no more. It's thought that Mars's thin atmosphere is to blame. The low pressure meant that, over time, most of the oceans just boiled away. With nothing to trap the heat, the low temperature means any water is frozen.

What isn't known is how long there was water on the surface. It could be that ancient Mars was warm enough to hold permanent oceans, but it could also be the case that the water spent most of its time frozen, and only thawed when a volcano eruption or meteor impact heated the planet enough to create a flash flood.

Scientists are intent on learning the history of Mars's water as it is linked to one of the biggest questions of all – are we alone? On Earth, where we find water we find life, and so by following the water on Mars, scientists hope they might be led towards life on a world other than our own.

EXPLORED BY: Mariner programme (1965–71); Viking (1976); Mars Global Surveyor (1997); Mars rovers (1997–2012); Mars Odyssey (2001); Phoenix (2008); ExoMars Trace Gas Orbiter (2016); InSight (2018)
NUMBER OF SPACECRAFT: 25+ ▸

Mover and shaker: Jupiter's vast bulk has shepherded large and small bodies around the Solar System

Jupiter

PLANET TYPE: Gas giant

Weighing in at 318 times the mass of Earth, Jupiter is the undisputed King of the Planets. Its huge mass not only keeps over 60 moons in check, but also corrals the other planetary bodies of the Solar System.

This includes the asteroid belt. Gaps in this region of the Solar System, known as the Kirkwood gaps, are in resonance with Jupiter. This means that the planet and asteroids regularly line up and over time, Jupiter's gravity yanks all the asteroids out of that orbit until there are none left.

On a grander scale, Jupiter's gravitational pull shepherded the planets into the positions we see today. It's thought that several worlds must have formed in a different location to where they currently reside, and were then shunted around the Solar System. The leading theory is that Jupiter took a 'grand tack' through the Solar System, drifting inwards before moving back out again. As it did so, the gas giant's huge mass upset the gravitational balance, causing the other planets to move around, and perhaps even eject some worlds entirely, before things finally settled into the configuration we see today.

EXPLORED BY: Pioneer 10 (1973); Pioneer 11 (1974); Voyager 1 (1979); Voyager 2 (1979); Galileo (1995); Juno (2016)
NUMBER OF SPACECRAFT: 6

Saturn

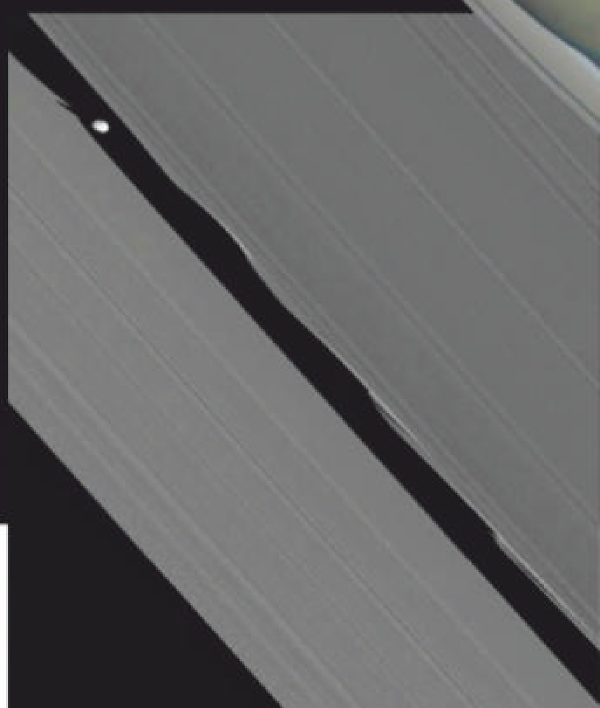
PLANET TYPE: Gas giant

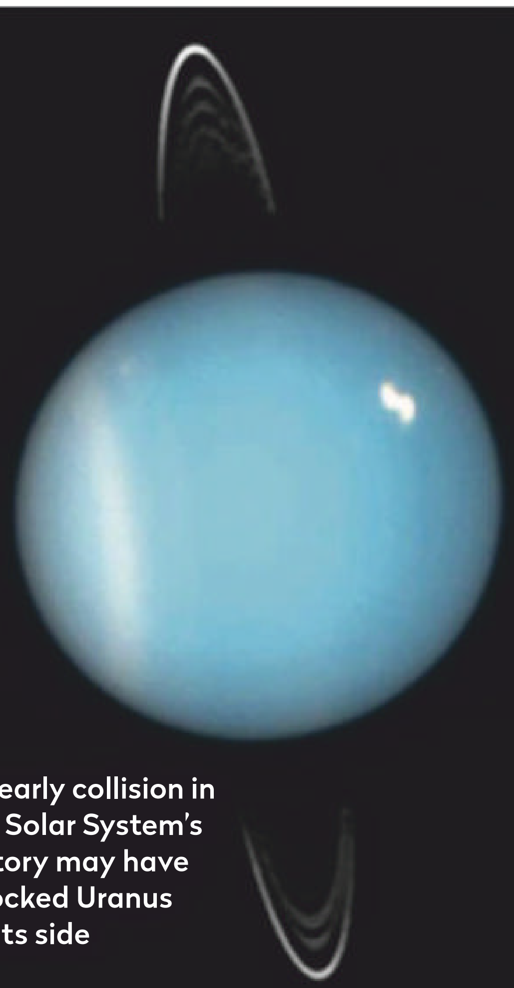
The rings of Saturn have captivated astronomers since they were first spotted in 1610. They are made up of billions of fragments of ice, ranging from the size of a grain of sand to boulders several metres across, creating a disc spanning 250,000km from side to side, but which is only 1km thick. Interactions with Saturn's moons pulls this disc into a series of rings, as well as creating beautiful wave patterns, which were captured in spectacular detail by the Cassini space probe.

It seems we might have been lucky to catch this sight, however, as recent measurements have found the rings are rapidly evaporating and could be gone in as little as 100 million years. Compared to Saturn's 4-billion-year age, that is no time at all, meaning the rings most likely didn't form at the same time as the planet. Instead, they were probably created in the relatively recent past, perhaps by the collision of two of Saturn's icy moons. The remnants of the collision then spread out to form the planet's famous rings.

EXPLORED BY: Pioneer 11 (1979), Voyager 1 (1980); Voyager 2 (1980); Cassini-Huygens (2004)
NUMBER OF SPACECRAFT: 4

▼ Saturn's moon Daphnis has pulled on the ring material creating ripples in its wake





An early collision in the Solar System's history may have knocked Uranus on its side

Uranus

PLANET TYPE: Ice giant

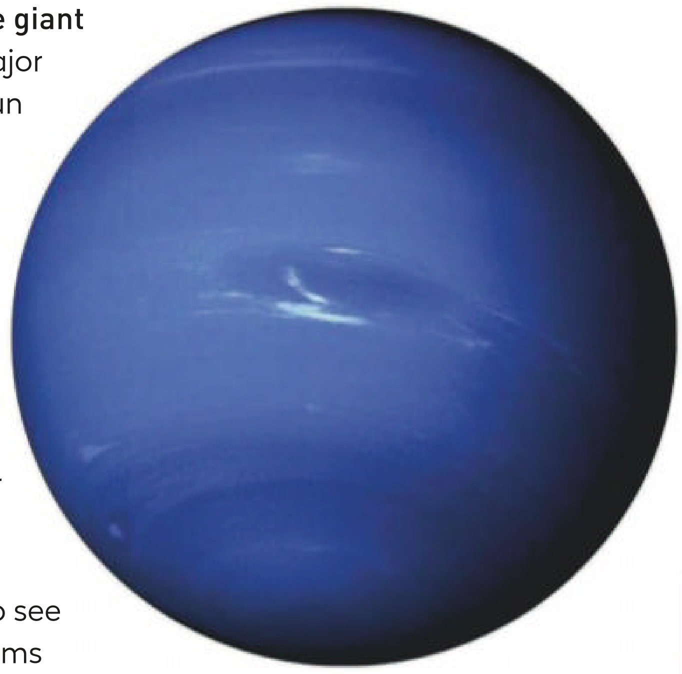
Uranus isn't much to look at. When Voyager 2 first flew past the planet in 1986, it found a uniform ball tinted sky blue by methane in the atmosphere. But looking beyond the calm exterior reveals a planet with winds that blow at speeds in excess of 900km/h in the wrong direction.

While most planets' spin axes are at right angles to their orbits, Uranus has been knocked over onto its side. No one is entirely certain why, but the lead theory is that an Earth-sized planetoid collided with Uranus early in the Solar System's history, tipping it over into its current configuration.

However, Uranus isn't always as calm as when Voyager 2 spied on it. As the planet takes 85 years to orbit the Sun, the seasons last for decades and the probe happened to pass by during the planet's northern summer. When Uranus passed into autumn in 2007, long-range observations found that the planet seemed to wake up, with storms creating bright spots the size of North America in the planet's atmosphere.

EXPLORED BY: Voyager 2 (1986)
NUMBER OF SPACECRAFT: 1

Neptune



▼ For such a remote planet, Neptune showed remarkable activity when Voyager 2 flew past in 1989

PLANET TYPE: Ice giant

As the furthest major planet from the Sun – and so the recipient of the least amount of solar energy – you might expect Neptune to be a relatively sluggish planet. But when Voyager 2 flew past in 1989, the mission team were astounded to see not only giant storms across the planet's deep blue atmosphere, but winds that blew up to 2,400km per hour. That's 15 times stronger than those found on Earth, and faster than on any other planetary body in the Solar System.

What drives these enormous winds is still a matter of great debate. It seems the extreme gusts only happen in the top 1,000km of the planet's atmosphere (Neptune is 49,250km in diameter), meaning it's unlikely the cause lies with some process occurring deep within the heart of the ice giant. Instead, it seems some shallow process that is limited to the upper layer of the atmosphere is at play, such as turbulence created by the condensation and evaporation of moisture.

EXPLORED BY: Voyager 2 (1989)
NUMBER OF SPACECRAFT: 1

The outer limits

Our solar family doesn't end at Neptune. Around 20 times the Earth-Sun distance from the centre of the Solar System there is a vast band of icy rocks left over from its formation, known as the Kuiper Belt. The New Horizons probe visited the region's most famous inhabitant, Pluto, in 2015, before carrying on to the minor planet Ultima Thule. There are hints of another planet about Neptune's size lurking here and astronomers are scouring the outer Solar System to confirm its existence.

Though we have explored our Solar System for over 60 years, there are countless questions space agencies seek to answer about its eight worlds. Missions are underway to investigate Mercury, Venus, Earth, Mars, Jupiter and the Kuiper Belt further. In 2020, two new rovers, ExoMars and Mars 2020, are set to make their way to the Red Planet, while JUICE and Europa Clipper will investigate the icy moons of Jupiter in the late 2020s. Hopefully the mysteries of the Solar System will be resolved before too long.

◄ The oddly shaped Ultima Thule was visited by New Horizons this year

BBC TWO

Presented by Professor Brian Cox, the six-part series *The Planets* is coming soon to BBC Two. Dates and times to be confirmed.

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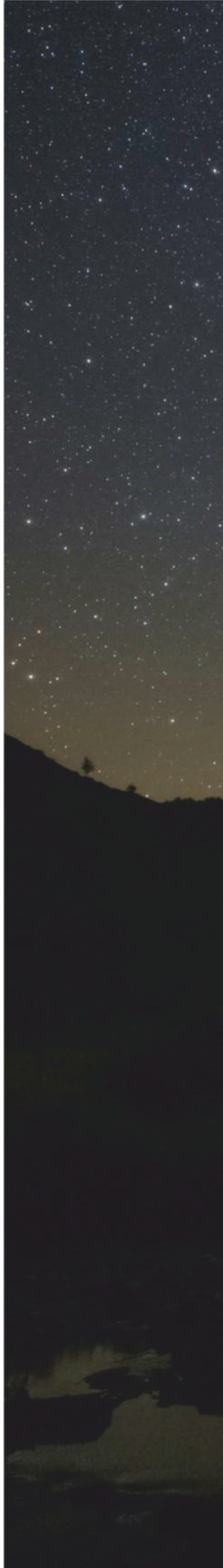


► This image of Mars, captured low in August 2018, uses Exmoor's natural features to frame the Red Planet – with a treelined horizon and watery foreground – against a backdrop of the Milky Way

PHOTOGRAPHING THE PLANETS

A fresh perspective

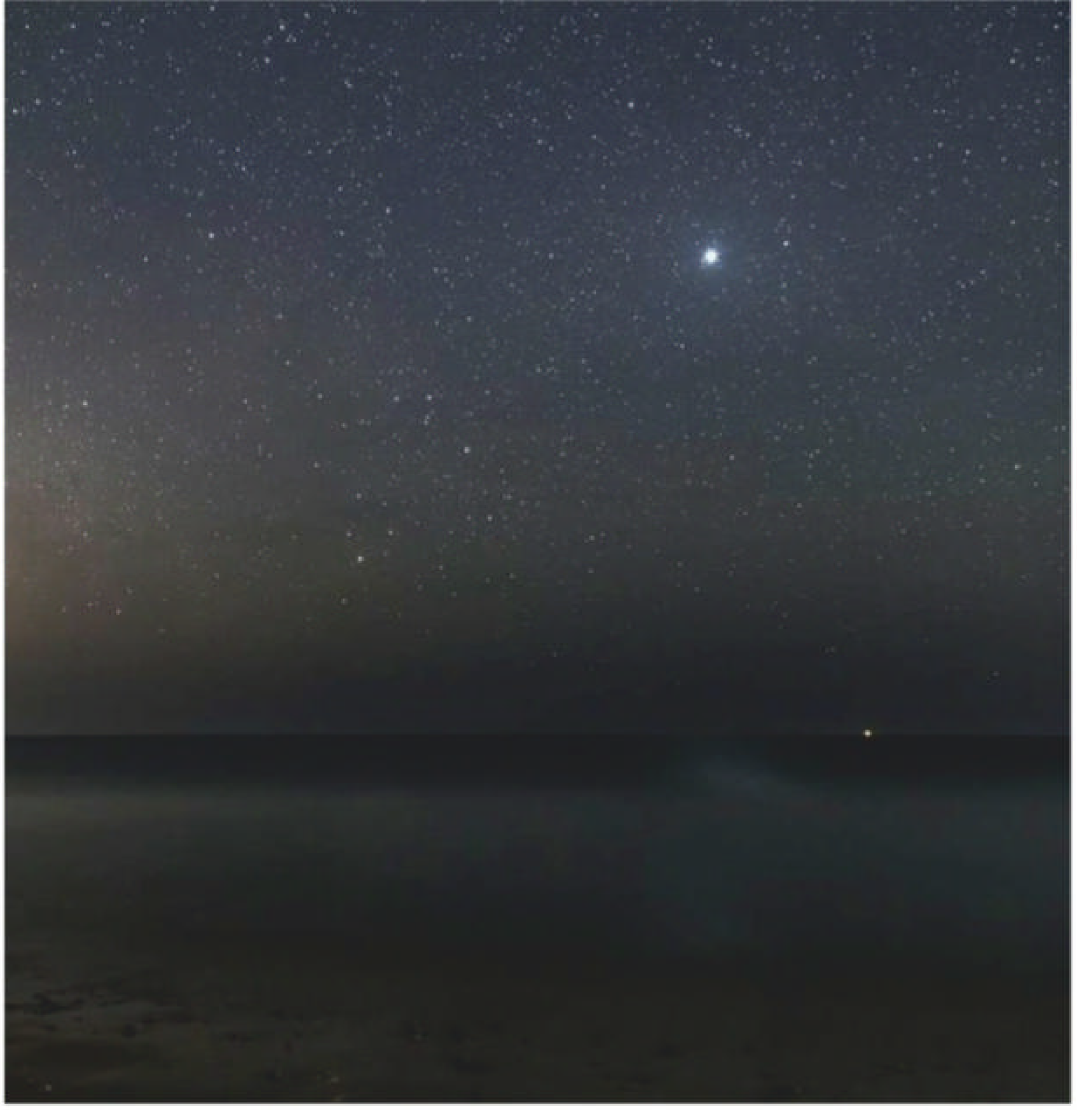
Astrophotographer **Will Gater** explores how to make the most of the current unfavourable positions of the planets, by using wide-field and nightscape imaging

Amateur photographers in the UK won't have failed to notice the last oppositions of Mars, Jupiter and Saturn. Unfortunately, as these planets skirt close to the horizon, they are susceptible to poor seeing conditions and are not ideal for high-resolution imaging. However, if you are willing to explore a different approach, a planet's low placement in the night sky can provide some unique astrophotography opportunities. As we'll show on the following pages, there's a plentiful supply of planetary imaging potential coming up. Take, for example, the low altitude of Jupiter and Saturn when they are at opposition over the next few years. While it's less than ideal for high-frame-rate imaging at long focal lengths, the fact that these planets are nearer the horizon could turn out to be rather helpful for nightscape astrophotography.

WILL GATER

In the frame

Nightscapes after all are, by definition, images where there's some ground element in the shot – such as a horizon, treeline or other landscape feature. If the planet you're trying to frame is sitting high in the sky, your compositional choices with this kind of photo can become quite limited. Unless you wait for a time when the planet is near to rising or setting during the hours of darkness, you'll have a large area of sky between the planet and the horizon to contend with. All that space can sometimes make a shot look unbalanced or, worse, lacking in a clear focal point.►



▸ A minimalist nightscape, taken looking out to sea from Charmouth in Dorset, captures Jupiter low in the sky

▸ With a planet lingering closer to the horizon, however, you'll often find the creative potential is greater. You'll be able to put more of the landscape into the image and, perhaps, find more visually interesting elements to include too.

How low can you go?

Another practical consequence of a planet being low is that longer focal length camera lenses come into play for nightscape work. The tighter fields of view provided by these lenses don't generally work for nightscapes of a planet that's high in the sky at

PROJECT 1 Capture a planet in context

A starry backdrop can help give planets a place in the Universe

Saturn appears as the largest point of light in this image, which makes use of the Millky Way's dust clouds

Planetary astrophotography needn't always be about large apertures and high-frame-rate cameras grabbing thousands of video frames. In fact long-exposure imaging, using the kind of equipment ordinarily used for wide-field, deep-sky work can be a wonderful way to show the worlds of our Solar System in the setting of their celestial surroundings on the sky.

While images like these won't show detail on our celestial neighbours, they do capture something of the immense scale of the cosmos, with shining beacons of planetary light set against a multitude of stars.

Jupiter and Saturn are currently located in parts of the sky that will provide a superb, sparkling backdrop for captivating wide-field images; during darkness this summer, Jupiter will sit in front of Milky Way dust lanes and dense star fields in Ophiuchus, while Saturn will be set against a similarly star-rich region in nearby Sagittarius.

What's perhaps most attractive about shooting long-exposure, wide-field images of the planets is how flexible the kit requirements are. They can be captured with DSLRs or CCD cameras, and the optics used could be anything from a longer focal length camera lens to a small, high-quality, refractor of the kind that's widely used by newcomers to deep-sky imaging. You will need a tracking mount to get the longer exposures required, and depending on your setup this could be as simple as a small portable tracking mount or as complex as a fully auto-guided equatorial system.

The basic approach for this kind of astrophotography is identical to simple deep-sky imaging. You will need to capture a series of long exposures – from a minimum 30 seconds to a few minutes in length, depending on your equipment – and then stack them together in software such as DeepSkyStacker. Final tweaking and enhancement can be done in image editing software like GIMP or Photoshop.

PROJECT 2 Go wide to grab a planetary system portrait

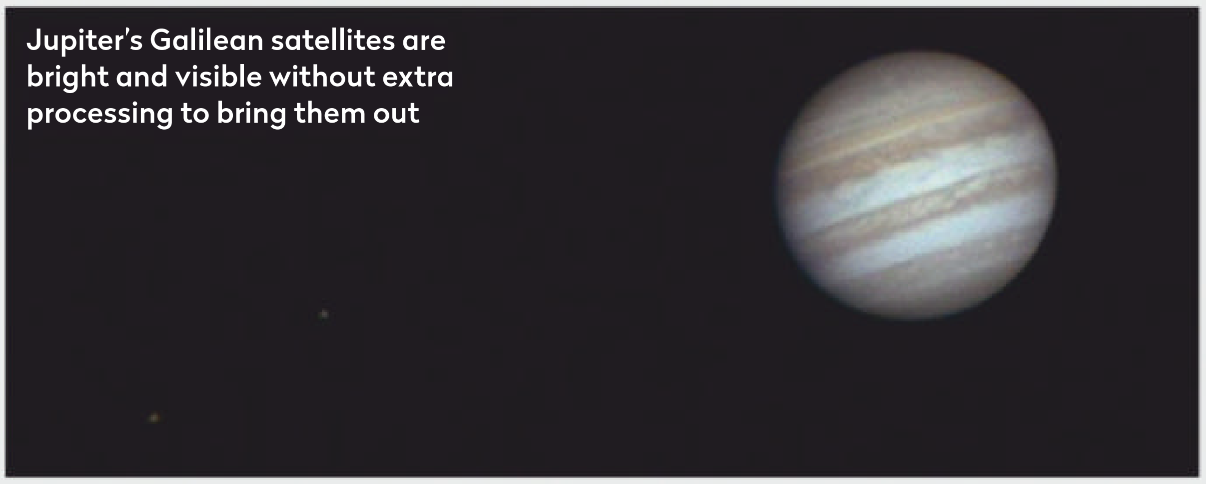
Zooming out means you can capture not just the planets, but their moons too

When a planet is low in the sky the undulating effects of poor seeing conditions – as the steadiness of the skies are known – can often be exacerbated. This, in turn, makes it more tricky to capture fine details at the high magnifications that are produced by typical high-resolution planetary imaging setups. These employ long focal-length, large aperture scopes and, often, a Barlow lens.

A way to get around this is to not use a Barlow lens, or similar magnifier, when imaging with a high frame-rate camera and this kind of equipment. This will mean you get a wider view of the planet, with its disc appearing smaller in the frame, but the benefit is that the effects of poor seeing will be less obvious. Any unsatisfactory seeing conditions will still degrade the image to a certain extent, but by lowering magnification you also get the advantage of a brighter – albeit smaller – planetary disc. This might mean that you can lower your camera's gain setting a little, which would have introduced unwanted image noise had it been set high when shooting at a higher magnification.

The biggest perk of a wider shot, though, is that it means you can capture some of the larger moons of Jupiter and Saturn alongside the planet itself. Sometimes, as is often the case with Jupiter's four Galilean satellites, the moons are bright enough that they show up in a shot that's been correctly exposed for the planet's disc. Other times, for example if you're trying to capture the fainter satellites of Saturn, you may need to capture two video files with your high-frame-rate setup: one exposed for the planet and the other with the exposure length, or gain setting, increased a little to show the dimmer moons. You can composite these two views in image editing software later – after, that is, they have been processed with analysis and stacking software such as RegiStax or AutoStakkert! If you're creating RGB colour images with a monochrome camera using this last technique, you may wish to simplify the process by capturing the three colour-channel videos required for the planet (red, green, blue) but then only capturing an unfiltered 'black and white' video for the faint moons themselves.


Saturn's moons are small, dim and far away, requiring extra processing work to appear

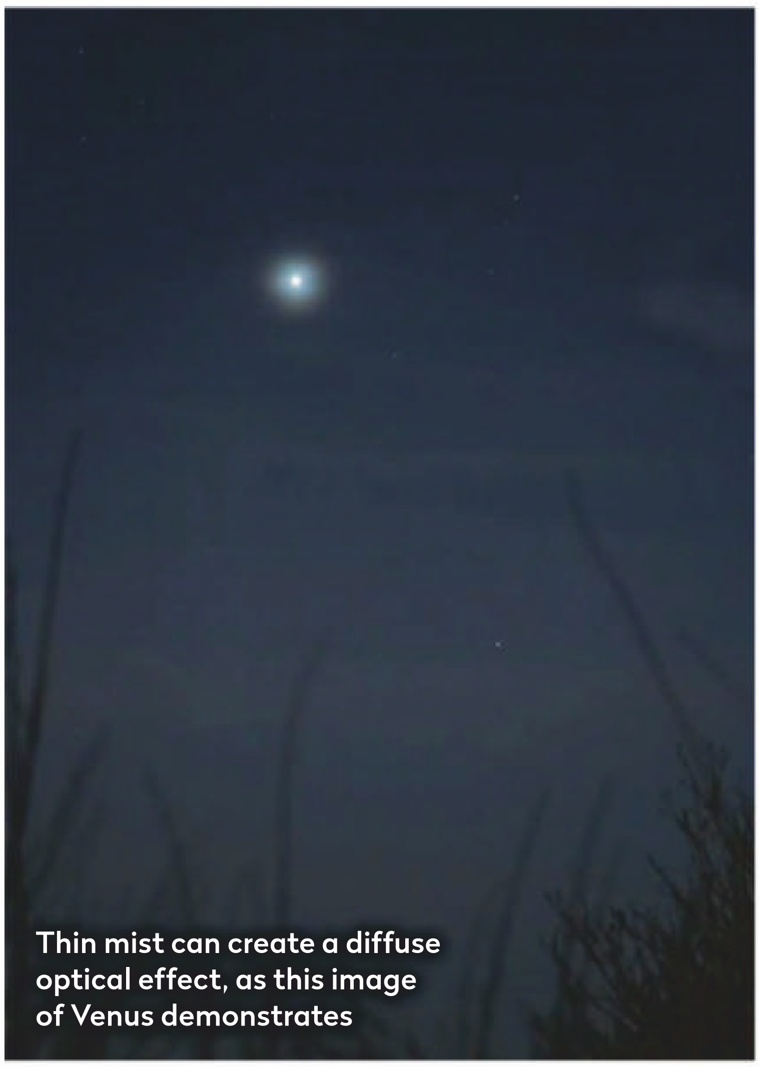

Jupiter's Galilean satellites are bright and visible without extra processing to bring them out

opposition. This only allows you a short window when the planet is close to rising or setting to get your target and an attractive foreground in the same frame.

If your target planet is below about 20° altitude when at opposition, as is the case with Saturn and Jupiter in 2019 and 2020, then it should fit easily within the field of view of a 50mm lens on a full format DSLR or an APS-C sensor DSLR if it's used in portrait orientation. With the wider views available from a full-format DSLR, even longer focal length lenses, in the 90-140mm focal-length range, can be used for planetary nightscapes. To do this you need to plan and compose the shot carefully to include interesting foreground features that are raised above the local horizon, like hedgerows, hills or mountains.

In such images the use of the longer focal length means the planet has a much greater prominence in the shot. It's worth bearing in mind that you can also enhance the nightscape's visual impact even further if the foreground you choose is distant enough to be in focus – at least roughly – along with the planet. This creates the illusion of the planet looming over an almost miniature landscape below. This is an effective technique for portraying not just low-altitude apparitions of the superior planets like Mars, Saturn and Jupiter but also Mercury, which always tends to hug the western horizon when it's ▸

A crescent Moon can help frame a nightscape. This twilight image shows Venus on the far left



Thin mist can create a diffuse optical effect, as this image of Venus demonstrates

▲ In this image of Jupiter (bottom left of the picture), the gas giant is set against the stars of Leo

WILL GATER X 3, SEBASTIAN VOLTMER/CCDGUIDE.COM, ISTOCK

▸ well placed in the evening twilight. This kind of composition really comes into its own when the Moon – especially when it is showing a thin crescent – or another world joins your target planet in the sky. Our pull-out monthly 'Sky Guide' will often contain alerts for just such events, but a few examples to highlight in the coming years include the meeting of Mars and Mercury after sunset later this month (see page 44) and the close pairing of Saturn and Jupiter in the evening skies during December 2020.

For imagers facing the prospect of battling poor transparency and jittery seeing conditions with high-frame-rate cameras and long focal-length scopes, it's worth considering wide-field planetary astrophotography. Given the current, unfavourable, run of apparitions, this can offer some practical freedoms. Perhaps the most counter-intuitive

PROJECT 3 Track a 'wandering star'

Capture the planet's meandering path across the sky

The retrograde motion of Mars can be shown in a montage of several images

If you're looking for a planetary imaging project that isn't adversely affected by the low altitude of your target then why not try capturing a planet's apparent motion against a dark, star-filled sky over the course of a few days or weeks. Jupiter, Saturn and Mars are perhaps the best targets for this as they move across the sky much more quickly than distant Uranus and Neptune.

Essentially what you need to do is record an image each night showing the planet – obviously – but crucially all the shots need to be centred on the same patch of starry sky every night. This is because later you're going to composite together all the shots you get so that the only thing that 'moves' between them should be the planet.

For this to work you need to have a setup that can record the planet, and the stars around it, well enough that you can easily overlay and align the resultant images. In principle, you can achieve this with a DSLR and a fast lens on a static tripod, though you may find it easier – if you have the kit available – to mount a camera and lens (or wide-field telescope) on a tracking mount and capture longer exposures.

If you decide to use a longer focal-length lens or scope for this, the nightly change in position of the planet will be more obvious. But be aware that you might only record the planet at a handful of locations before it moves out of the fixed field of view. You may, therefore, find it best to use a lens of, say, 50-100mm focal length.

Once you've got at least several nights' worth of shots, bring them into a layers-based image editor and load them as separate layers within one image file. It's likely you'll need to tweak each layer's position and orientation so the star fields are aligned. Once they are, set each layer's 'blend mode' to 'lighten', whereby the planet should appear in multiple places across the frame – its wandering across the sky revealed.

Will Gater is an astronomy writer and presenter. Follow him on Twitter at @willgater or visit willgater.com

example is that thin cloud or mist – which can hamper high-resolution imaging – occasionally enhances, rather than ruins nightscapes and wide-field images of the planets. It can diffuse the light of the planet, revealing the object and its colour much more clearly. The image of Venus (opposite page, bottom left), low down and shining through mist, shows this effect, which, if visible, could augment night time photos of the brighter planets near the horizon in coming years.

Perfect pairing

Another often overlooked advantage of the low altitude of Jupiter and Saturn is that their sky position often wanders in and around the starry band of the Milky Way, meaning there are some fantastic long-exposure deep-sky imaging opportunities available. These techniques can be used to create interesting images of not just Jupiter and Saturn, but Mars and two often overlooked planets, Neptune and Uranus – the latter of which is, in fact, well placed for observation and high-resolution astrophotography in the coming years.

So, while high-resolution planetary imaging might be off the table until 2022 – when the 'big-three' are due to get high in the sky again – there's no excuse to sit around twiddling your thumbs – not when there are so many ways to use their positions to create some really memorable astrophotographs.

16-PAGE CENTRE PULLOUT

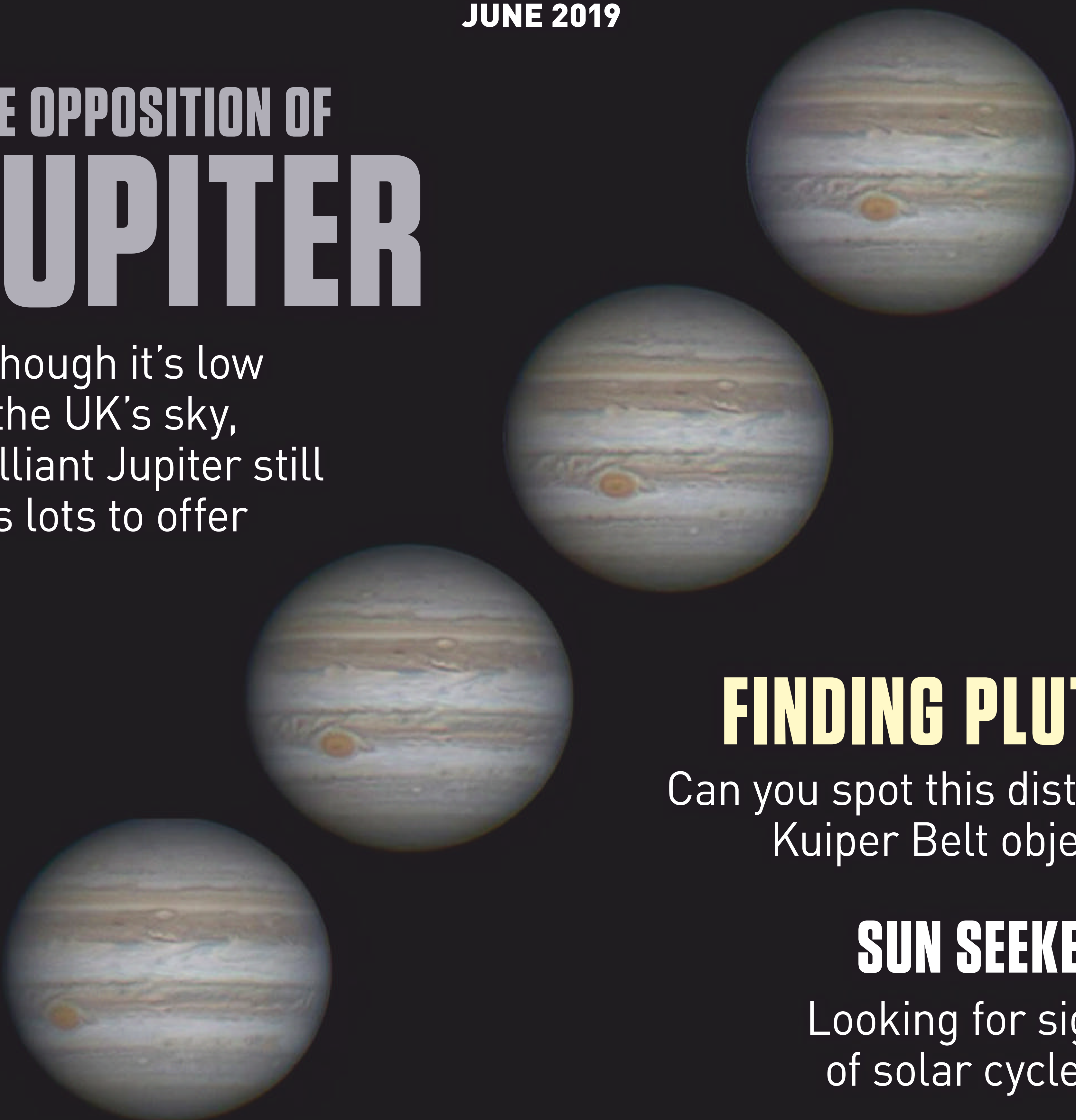
BBC Sky at Night MAGAZINE

The Sky Guide

JUNE 2019

THE OPPOSITION OF JUPITER

Although it's low in the UK's sky, brilliant Jupiter still has lots to offer



PETE LAWRENCE

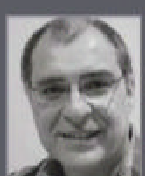
FINDING PLUTO

Can you spot this distant Kuiper Belt object?

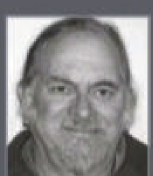
SUN SEEKERS

Looking for signs of solar cycle 25

About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Don't miss...

✦ Noctilucent clouds in the evening and morning skies

✦ The 'Moon illusion' as it appears huge in the sky

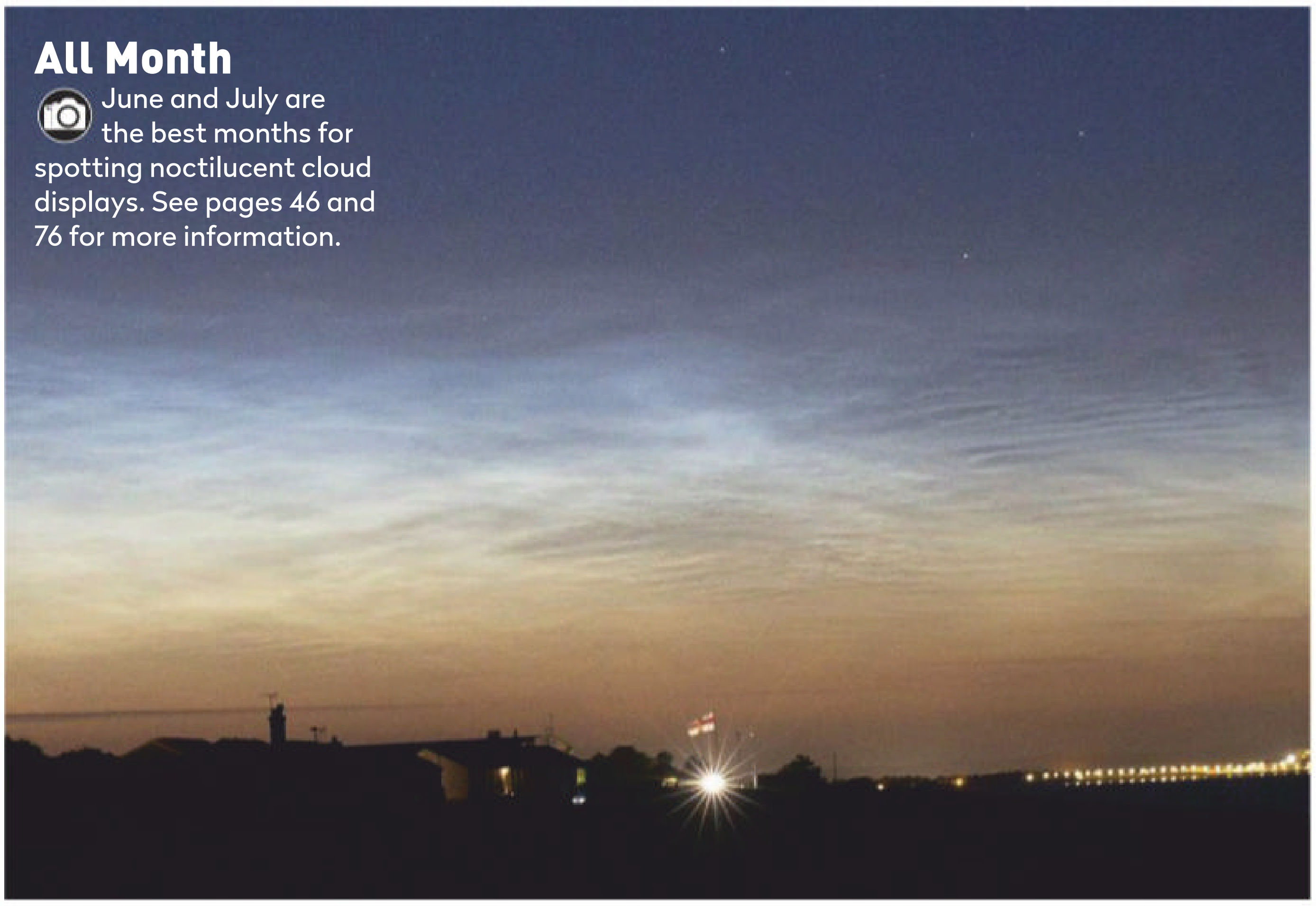
✦ Mars in conjunction with Mercury

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky, sign up to our newsletter: **www.skyatnightmagazine.com/iframe/newsletter-signup**

JUNE HIGHLIGHTS

Your guide to the night sky this month



All Month

June and July are the best months for spotting noctilucent cloud displays. See pages 46 and 76 for more information.

Saturday 1

Early risers may catch a glimpse of mag. –3.8 Venus 9˚ from a slender 6%-lit waning crescent Moon. You'll need to be quick though as they are only up 30 minutes before sunrise. Look low towards the east-northeast.

Tuesday 4

Look low in the northwest, 30-40 minutes after sunset for Mercury, 4.8˚ north of a waxing crescent Moon.

A double transit and shadow transit take place on Jupiter from 00:30 BST (23:30 UT), involving Io and Ganymede.

Sunday 9

This evening is a good time to catch our Moon Watch target, the crater Julius Caesar.

Monday 10

Magnificent Jupiter reaches opposition today.

Wednesday 12

During early evening the clair obscur optical effect known as the Jewelled Handle is visible on the Moon. This occurs when the peaks of the Jura mountains – which border Sinus Iridum – catch the lunar dawn sunlight.

Sunday 16 ▶

This evening's full Moon rises very close to mag. –2.5 Jupiter. A low rising full Moon also presents a great opportunity to see whether you can experience the 'Moon illusion', an effect which makes the Moon appear artificially huge.

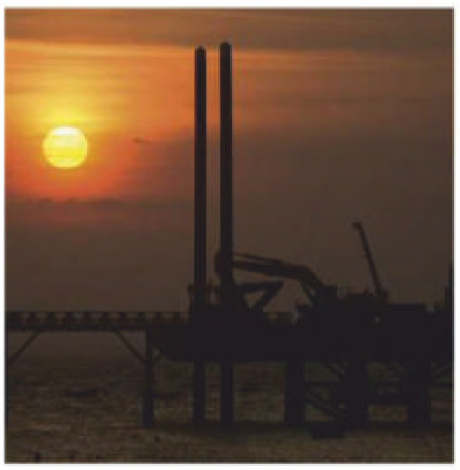
Wednesday 19

This evening's virtually full Moon lies 1.5˚ southwest of mag. +0.6 Saturn.

At midnight BST (23:00 UT) a telescopic view of Jupiter will show Callisto just to the north of Jupiter's disc.

Friday 21 ▶

At 16:54 BST (15:54 UT) the Sun reaches its most northerly point in the sky (highest declination) a point in time marking the Northern Hemisphere's summer solstice.



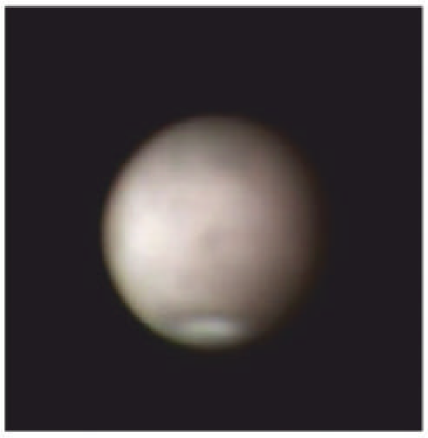
Sunday 23

Mercury reaches a greatest eastern elongation of 25.2° and is currently visible low above the northwest horizon after sunset.

PETE LAWRENCE X 7

Monday ▶

3 This evening Jupiter appears to have a new moon as the planet passes near to the mag. +9.3 star HIP 84543.



◀ Wednesday

5 Mag. +1.8 Mars is just 4° from this evening's 7%-lit waxing crescent Moon.

Saturday

8 A telescopic view of the Moon around 23:00 BST (22:00 UT) will reveal a delicate necklace of lights, as peaks on the rim of crater Alexander catch the Sun.

At 01:20 BST (00:20 UT), Europa will appear centrally in front of Jupiter's disc.

Thursday

13 This evening, there's another chance to see a Galilean moon and its shadow pass across Jupiter's disc almost in sync. View from around 22:00 BST (21:00 UT).

Saturday

15 This evening the 97%-lit waxing gibbous Moon lies close to Jupiter and the red-supergiant Antares (Alpha (α) Scorpii).

Monday

17 This evening and over the next few evenings, mag. +1.8 Mars will lie very close to mag. +0.3 Mercury. The pair may be seen soon after sunset, low in the northwest. On 18 June the separation is just 14 arcminutes.

Friday

28 Peak of the weak June Bootid meteor shower. The peak Zenithal Hourly Rate (ZHR) is just 5 meteors per hour.

Family stargazing – 'Moon illusion'

The fuller phases of the Moon look huge when low to the horizon. This false effect is known as the Moon illusion and is very strong, tricking even experienced night watchers. Look for the full phases of the Moon rising around 21:00 BST (20:00 UT) on 16 June, 22:00 BST (21:00 UT) on 17 June and 23:00 BST (22:00 UT) on 18 June, and see whether your young observers can fall for its trickery too. Hold a little finger up at arm's length to cover the Moon's disc, making note of its size. Then repeat when the Moon is higher in the sky to show it is an illusion after all.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_Lessons** for our 10-step guide to getting started and **http://bit.ly/First_Tel** for advice on choosing a scope.

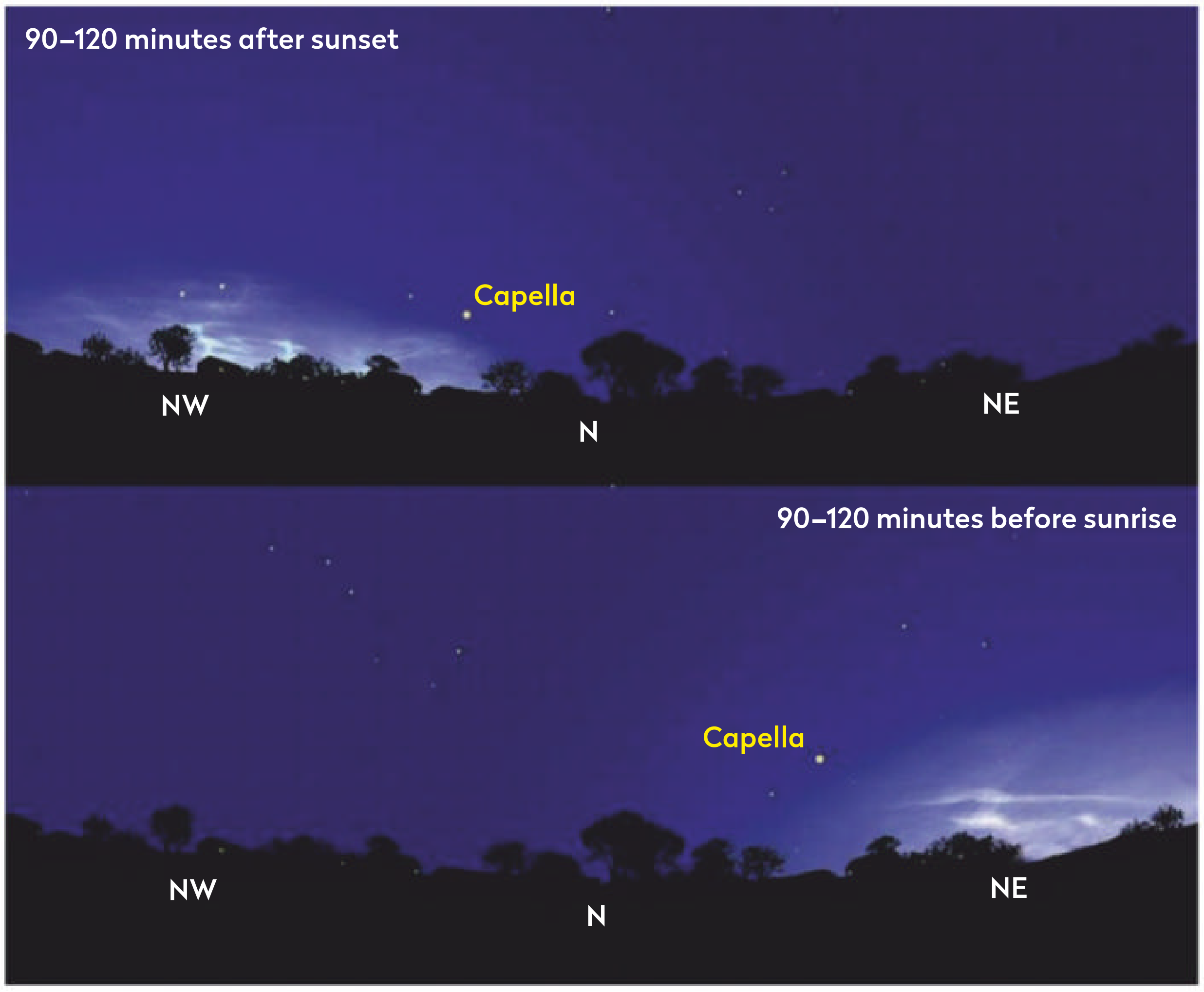
DON'T MISS

Noctilucent CLOUDS

BEST TIME TO SEE: All month with darkest skies apearing at the start and end of the month

The night sky during June and July doesn't get fully dark across the UK, an effect that gets worse the further north you live. As we approach the June solstice, which occurs at 16:54 BST (15:54 UT) on 21 June, the orientation of Earth's axis is such that the northern part of the axis is tilted in the Sun's direction giving the Northern Hemisphere its period of summer.

From the UK, the Sun rides high across the sky during the middle of the day in June. At night it dips by only a small amount below the northern horizon, never allowing our skies to darken properly, causing issues with night time astronomy as it does so. A saving grace is the phenomenon known as noctilucent clouds or NLCs. You may think that getting excited over clouds represents astronomical treachery but NLCs are quite special.



▲ After sunset NLCs may track from northwest (top), via north, to northeast by morning

They form when water ice crystalises around seeding particles located in a thin layer of the mesosphere, around 82km up. The seeding particles mostly come from the fine dust left behind after a meteoroid vaporises in the atmosphere but may also appear from man-made sources such as rocket exhausts. A typical NLC ice particle is around 40–50nm in size.

A beautiful display of noctilucent clouds from last year's season

It's only during the period from late May through to early August that this part of the mesosphere dips to a sufficiently low temperature to allow the formation of the ice clouds that we see as NLCs – a rather counterintuitive situation considering this is the Northern hemisphere's summertime.

NLC appearance is delicate and easily lost when the sky is too bright. If present, they become visible when the Sun's altitude is between –6° and –16° (minus indicating below the horizon). This means that, from the UK, NLCs should start to be visible between 90-120 minutes after sunset and a similar time before sunrise.

Displays low above the northwest horizon in the evening, or low above the northeast horizon in the morning are most common, although extensive outbreaks of NLC activity may bridge the gap, persisting all night. In such cases the display first appears in the northwest, moves through north and then into the northeast, tracking the position of the Sun as it moves beneath the horizon.

There is no way to guarantee a display. Last year was rich but this followed several weak seasons. Patience and tenacity are required and these are rewarded if you are lucky enough to spot an extensive display.

Turn to page 76 for imaging tips

ALL PICTURES: PETE LAWRENCE

Solar cycle 25

BEST TIME TO SEE: Whenever the Sun is shining

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

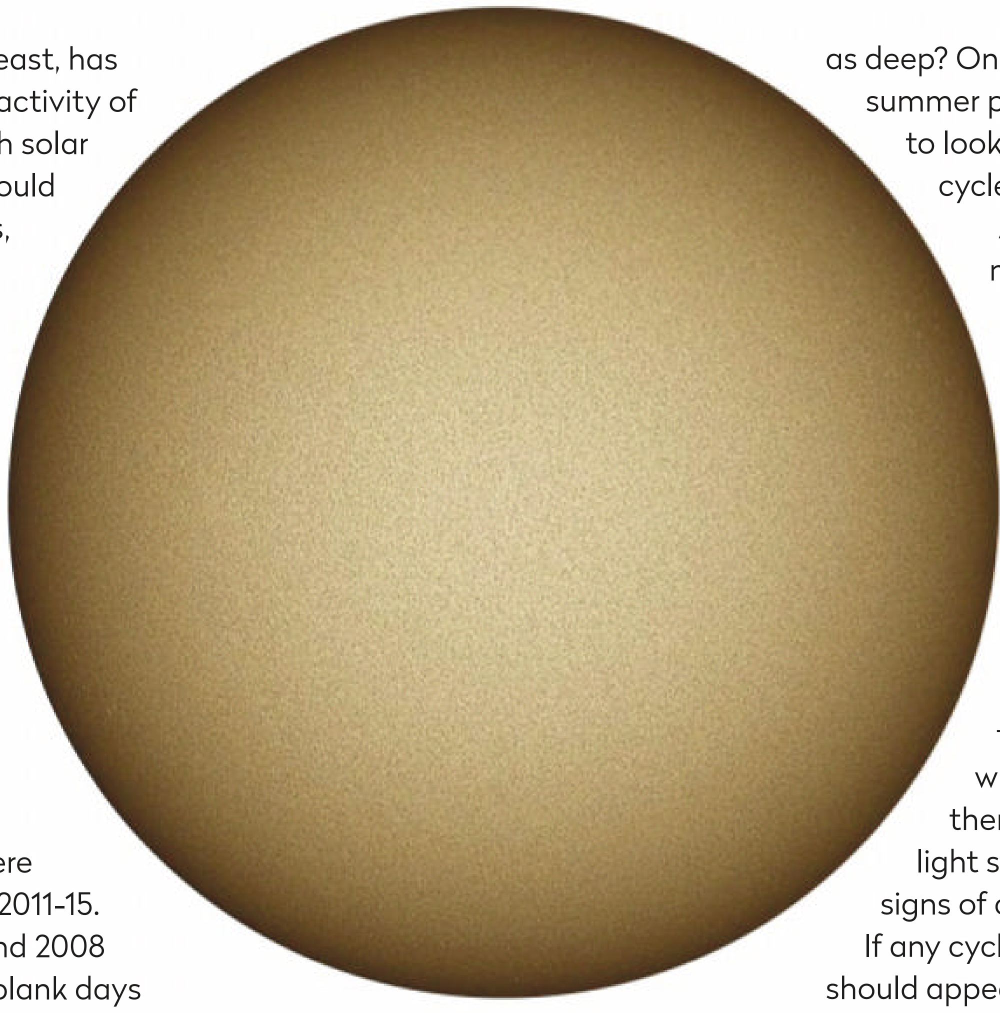
The Sun, in white light at least, has not been showing a lot of activity of late. As we have passed through solar minimum, a period when you would normally expect fewer sunspots, the Sun has been putting on a rather blank face. All eyes, safely protected behind the appropriate filters of course, have been looking for evidence of the start of the next activity cycle, known as solar cycle 25.

Last year the Sun presented us with 221 blank days, days when there were no sunspots visible. Prior to this, 2017 had 104 blank days but in the years running up to this the figure was much lower; there were hardly any spot-free days from 2011-15.

The last solar minimum around 2008 had 70 blank days in 2006, 152 blank days in 2007, 268 days in 2008 and 260 days in 2009. Will the cycle 24-25 transition be as deep? Only time will tell, but this summer presents a great opportunity to look for evidence of the next cycle yourself.

As ever, telescopes and eyes must be completely protected. A certified full aperture white light filter is the best option, the filter material typically being available in an A4 sheet for less than £30. A bit of DIY with cardboard, sticky-backed plastic and scissors is all that is needed to build your own filter. Fitted over the front of your scope and with the finder capped, it is then possible to monitor white light solar activity looking for early signs of cycle 25.

If any cycle 25 spots do appear, they should appear at mid-heliospheric latitudes – ie, roughly mid-way between the poles and the equator.



▲ **Nothing to show: the Sun at Solar minimum presents a spotless face**

Galilean moon shadows

BEST TIME TO SEE:
4, 8 & 13 June at the times shown on the graphic

▲ **Double moon and shadow transit, from 00:30–03:52 BST (23:30–02:52 UT), 5 June**

▲ **Europa and its shadow in transit from 23:53–02:32 BST (22:53–01:32 UT), 7 and 8 June**

▲ **Io and its shadow in transit from 21:45–00:06 BST (20:45 –23:06 UT), 13 and 14 June**

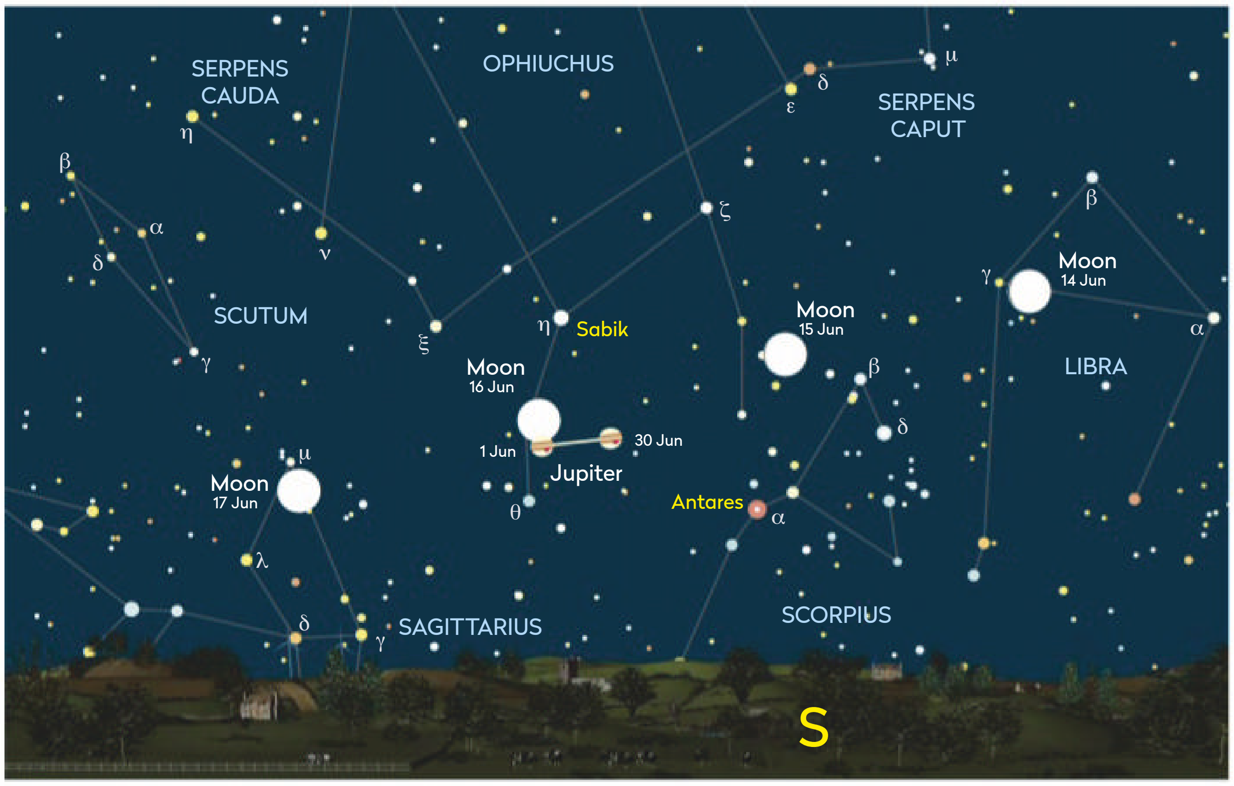
The four giant Galilean moons of Jupiter present an ever-changing ballet for those of us lucky enough to be able to view this spectacular world through the eyepiece of a telescope. As they pass around the planet, they tend to stay close to the gas giant's equatorial plane. Passing between Jupiter and the Sun, they cast huge, impressive dark shadows on the Jovian atmosphere below.

Before opposition, the geometry of this arrangement is such that a shadow precedes the moon casting it. After opposition a shadow follows its moon. If you're a regular observer of Jupiter this shifting order is very evident.

However, there's a third arrangement which occurs close to opposition and is quite spectacular. Here, the alignment is such that the moons line up with their shadows. As each moon transits across the planet's disc, so its shadow marches along in sync. The relative position of Jupiter, the Galilean moons and the Sun normally means that the shadow can still be seen either north or south of the moon as the pair transit. When Jupiter is close to an equinox (the next will happen in 2021) the alignment is much tighter and, the moon can overlay its shadow.

Jupiter reaches opposition on 10 June and there are several transits worth looking for during this period as shown in the graphic.

THE PLANETS Our celestial neighbourhood in June



▲ Although Jupiter is low in the sky, it's well worth taking a look as it moves slowly westward

PICK OF THE MONTH

Jupiter

Best time to see:
10 June, 01:00 BST (00:00 UT)
Altitude: 14.5˚
Location: Ophiuchus
Direction: South
Features: Complex banded atmosphere, Galilean moons
Recommended equipment:
75mm scope or larger

PETE LAWRENCE X 3

Jupiter reaches opposition on 10 June but its low southerly aspect means that, from the UK, we don't get a good look at it. From the centre of the country it only has an altitude of 15˚ maximum when due south. Any view we get is likely to be compromised by the poor seeing conditions at a low altitude.

▲ Jupiter, as observed in June 2018. The Great Red Spot can be seen with a 100mm telescope

Despite this, it's always worth having a look, just in case you get lucky and conditions are still. Jupiter is currently quite bright at mag. –2.5, and therefore does have the virtue of being easy to find.

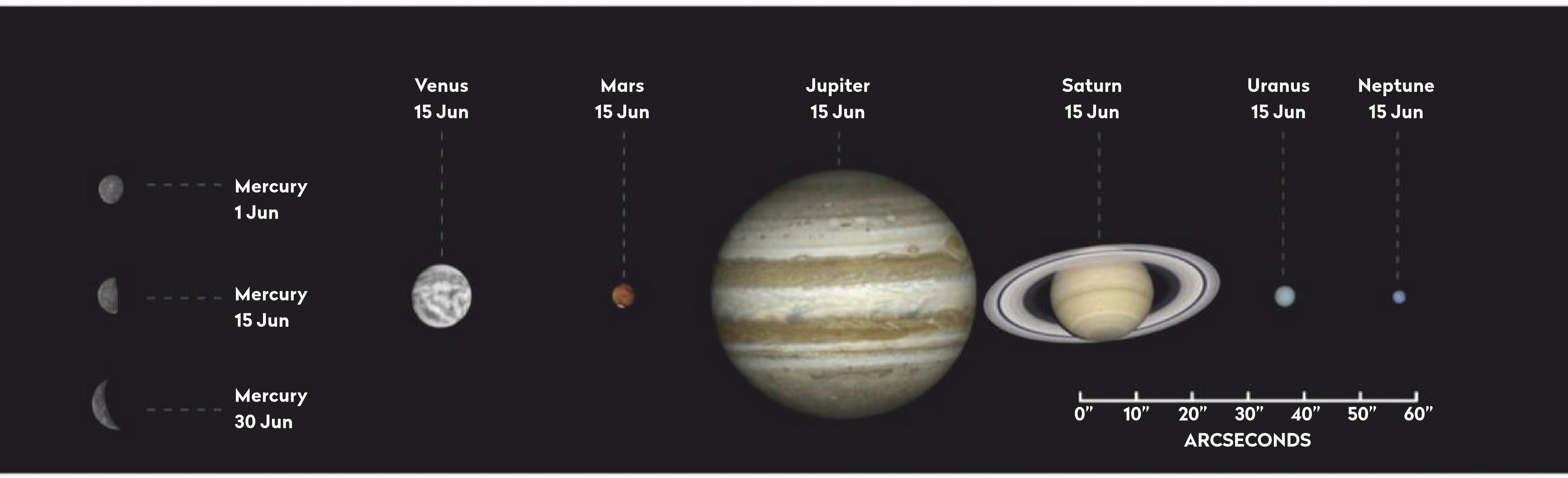
The planet is currently located in the southern regions of Ophiuchus and can be seen moving slowly westward throughout June. The full Moon on 16 June, itself technically at opposition, will lie a little over 2˚ from Jupiter as it climbs higher in the sky as darkness falls.

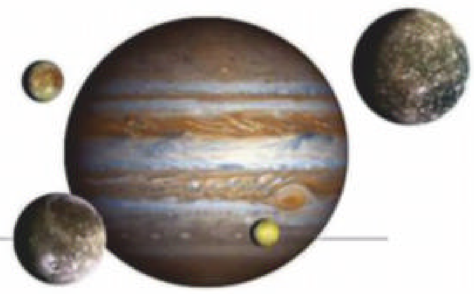
A telescope of any size will show the planet's flattened disc along with its two dark bands; the South Equatorial Belt (SEB) and the North Equatorial Belt (NEB). A scalloped hollow on the southern edge of the SEB is the home of the famous Great Red Spot (GRS), a storm several times the size of Earth. It can be glimpsed with a 100mm scope but it has to be on the Earth-facing side of Jupiter to be seen.

In addition to the planet and its atmospheric details, Jupiter's four largest and brightest satellites, the so-called Galilean moons, are always interesting to watch. As opposition is reached, a transit of one of the Galilean moons will be accompanied by its shadow passing across the atmosphere below in sync with its moon.

The planets in June

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 23 June, 50 minutes after sunset
Altitude: 5° (low)
Location: Gemini
Direction: West-northwest

Mercury reaches greatest eastern elongation on 23 June, when it appears separated from the Sun by 25.2° in the evening. It spends the main part of June heading to this position and is well placed as long as you have a flat horizon towards the northwest. Mercury also has a close encounter with the now dimming Mars, appearing separated by just 14 arcminutes on the evening of 18 June. Mars will be mag. +1.8, so trickier to see than mag. +0.3 Mercury. Mercury drops south below the ecliptic towards the end of the month, making it harder to see.

Venus

Best time to see: 30 June, 30 minutes before sunrise
Altitude: 2° (very low)
Location: Taurus
Direction: Northeast

Mag. –3.8 Venus rises 45 minutes before the Sun on the morning of 1 June. On this date the planet is joined by a 5%-lit waning crescent Moon, 8.7° to the southwest. An interesting battle – between shrinking apparent separation from the Sun and steepening ecliptic angle – keeps Venus's rise time around 45 minutes before sunrise all month. On 1 June it appears 93%-lit and 10 arcseconds across while, on 30 June, it's almost fully lit with a 97% phase and just 9 arcseconds across.

Mars

Best time to see: 1 June, 23:15 BST (22:15 UT)
Altitude: 3.5°
Location: Gemini
Direction: Northwest

Although Mars is not well placed for telescopic observation at present, it remains stubbornly in the evening twilight. On 5 June a slender 7%-lit waxing crescent Moon can be seen 4° to its left. Then on 17-19 June, mag. +1.8 Mars is joined by brighter, mag. +0.3 Mercury. Both planets will be visible low above the northwest horizon from around 22:15 BST (21:15 UT).

Saturn

Best time to see: 30 June, 01:45 BST (00:45 UT)
Altitude: 15°
Location: Sagittarius
Direction: South

Saturn is a morning object in Sagittarius, located east of the Teapot asterism and south of the Teaspoon asterism. The planet brightens from mag. +0.6 at the start of June to mag. +0.5 at the end when it reaches maximum altitude, around 15°, above the southern horizon. The planet's northern pole is tilted towards Earth by 24°. The Moon is close to Saturn on 19 June. Its almost fully illuminated disc lies just 1.5° to the southwest when both are due south.

Neptune

Best time to see: 30 June, 01:30 BST (00:30 UT)
Altitude: 9° (low)
Location: Aquarius
Direction: East-southeast

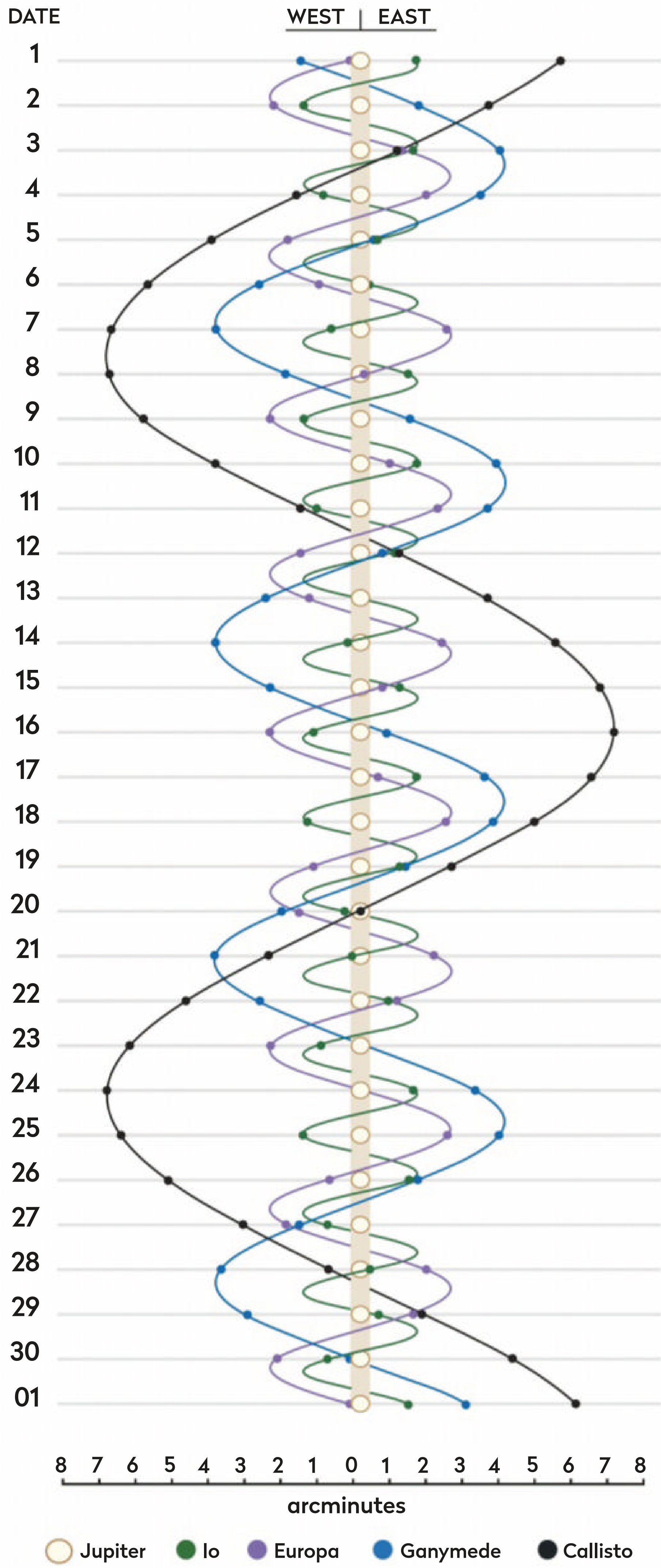
Neptune is a tricky planet to spot. It's a morning object and at mag. +7.9 is affected by the dawn twilight. Your best chance is to use binoculars at the month's end when it will be located 1.3° east-northeast of mag. +4.2 Phi (φ) Aquarii.

Not visible this month
Uranus

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JUNE

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JUNE

Explore the celestial sphere with our Northern Hemisphere all-sky chart

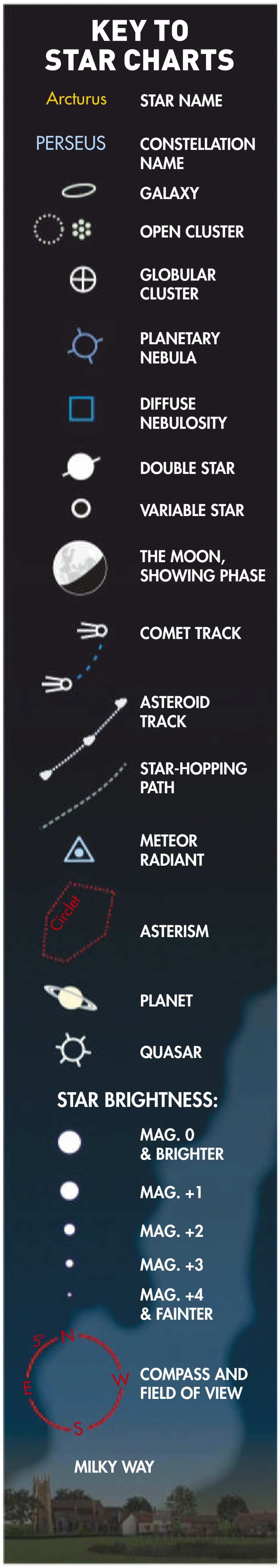


CHART: PETE LAWRENCE

When to use this chart

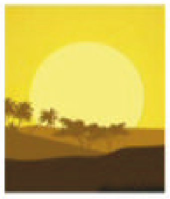
1 June at 01:00 BST
15 June at 00:00 BST
30 June at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

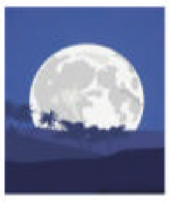
1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in June*



Date	Sunrise	Sunset
1 Jun 2019	04:48 BST	21:28 BST
11 Jun 2019	04:42 BST	21:38 BST
21 Jun 2019	04:41 BST	21:43 BST
30 Jun 2019	04:45 BST	21:42 BST

Moonrise in June*

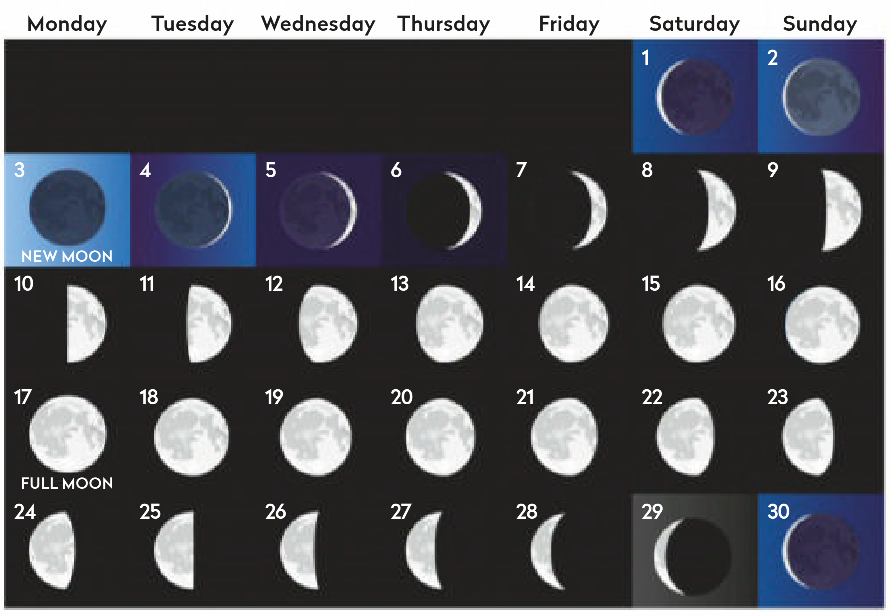


Moonrise times

1 Jun 2019, 04:18 BST	17 Jun 2019, 21:51 BST
5 Jun 2019, 06:37 BST	21 Jun 2019, 00:05 BST
9 Jun 2019, 11:35 BST	25 Jun 2019, 01:30 BST
13 Jun 2019, 16:59 BST	29 Jun 2019, 02:42 BST

*Times correct for the centre of the UK

Lunar phases in June

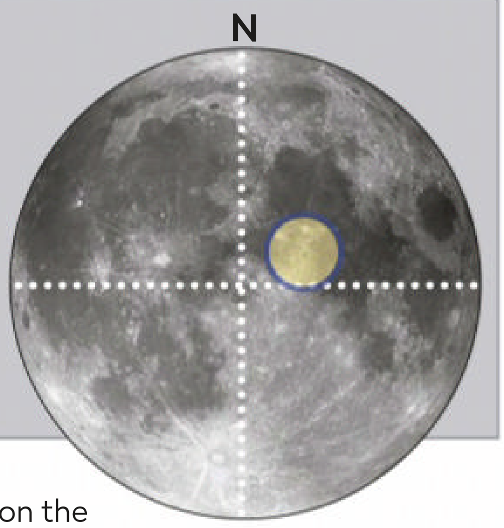


More **ONLINE**
Paul and Pete's Virtual Planetarium

MOONWATCH June's top lunar feature to observe

Julius Caesar

Type: Crater
Diameter: 91km
Longitude/latitude: 15.2° E, 9.2° N
Age: Older than 3.9 billion years
Best time to see: 6 days after new Moon (9 June) and five days after full Moon (23 June)
Minimum equipment: 50mm refractor



Julius Caesar is a broken crater located on the western shores of Mare Tranquillitatis. Its 91km diameter form appears battered and broken with only the western half of its rim well defined. Lava has flowed within its boundary, smoothing its floor with the northern section of the floor looking smoother and darker than the rest. The eastern rim is so eroded that it's hard to make out convincingly. A number of ridges and cliffs appear to describe the continuation of the rim but it's by no means obvious which ridges belong to Julius Caesar. The crater is around 3.4km deep and covers around 3,000 square kilometres, similar to the area of Gloucestershire.

The eastern rim of the crater Julius Caesar is so eroded that it's hard to make it out convincingly

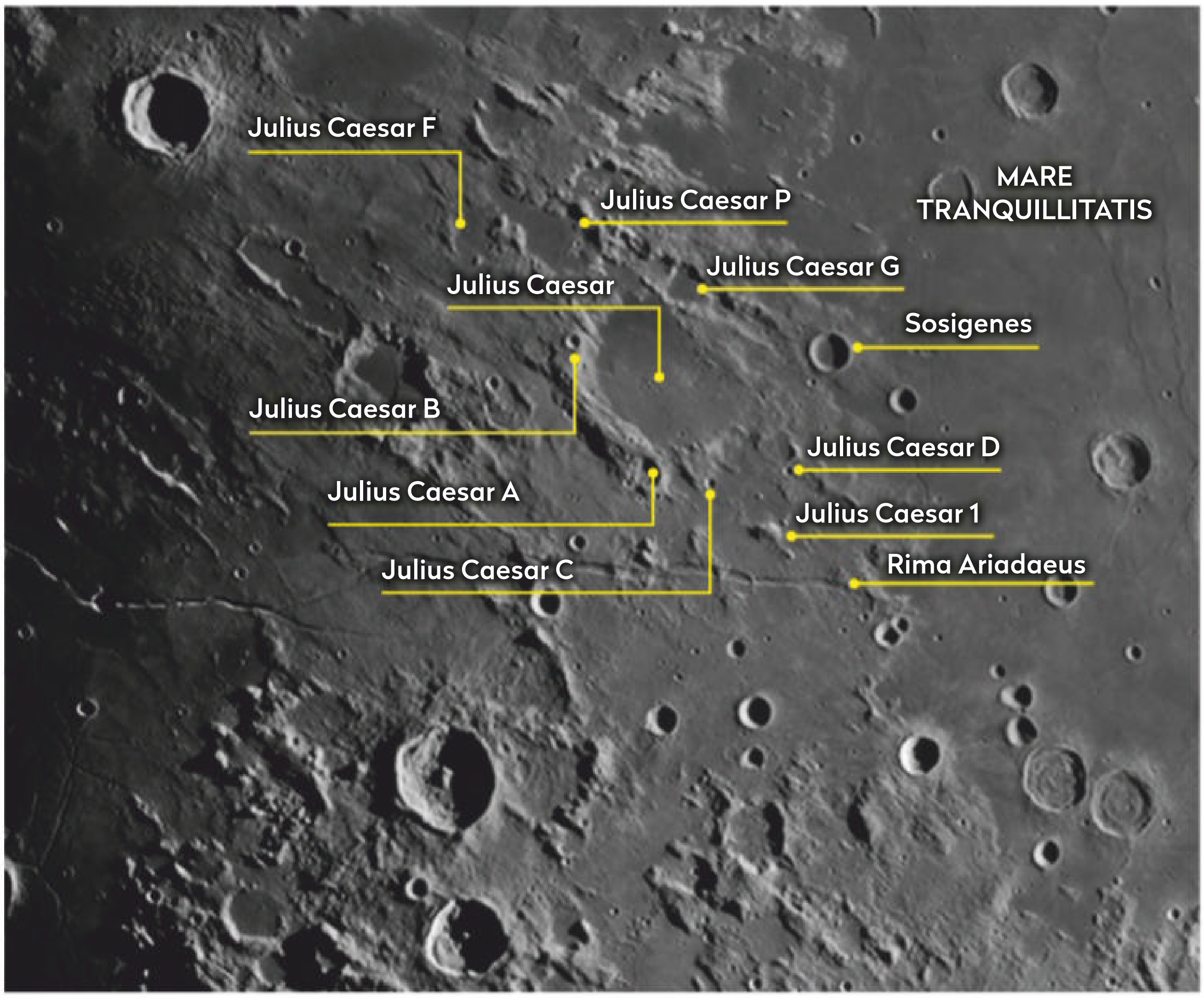
Despite its proximity to Mare Tranquillitatis much of the overlying material that makes Julius Caesar harder to discern is believed to have originated from the massive impact that formed the Mare Imbrium basin located in the northwest quadrant of the Moon's Earth-facing hemisphere. There's a linear grooving going on here, a line of material running from the northwest – the direction of Mare Imbrium – to the southeast.

A number of small satellite craters appear dotted around the edge of the main crater. To the south west is 13km **Julius Caesar A**. This has a flat floor and an almost tear drop outline. Its shape contrasts well with the circular form of 7km **Julius Caesar B** embedded in the northwest rim of Julius Caesar. Following the satellite lettering sequence then becomes something of a resolution test for your scope. At the south of the main crater lies 5km **Julius Caesar C**. A 100mm telescope is required to see this. Located 36km to the southeast of C lies similarly sized 5km **Julius Caesar D**.

Shifting the view to the northeast section of Julius Caesar's rim, brings in 20km **Julius Caesar G**, an irregular feature filled with the same tone of dark lava as that found in the northern half of the main crater. 37km **Julius Caesar P** to the northwest is also irregular and lava filled, giving the appearance more of a lunar 'lake' than a crater. It adjoins 19km **Julius Caesar F** immediately to its west. A number of volcanic shields are visible in the region, many dotted around the rim of Julius Caesar P with one to the north and one to the south of Julius Caesar F. A further example of a shield volcano can be seen to the south of Julius Caesar, just to the north of the impressive graben known as Rima Ariadaeus. Known as **Julius Caesar 1**, this complex volcanic shield measures 28x14km in size.

While looking at Julius Caesar it is hard not to be distracted by 18km **Sosigenes**, which lies immediately to the east. Despite its diminutive size, this is an impressive feature. It's round in shape with a steep inner rim slope, which looks very consistent all the way around. Radial variations in albedo exist here, which may make an interesting target for high resolution imaging setups. The floor of Sosigenes looks completely flat, almost giving the impression that someone has created a beautiful circular swimming pool on the Moon.

▼ **Julius Caesar covers 3,000 square kilometres, making it similar in size to Gloucestershire**



PETE LAWRENCE X 5

COMETS AND ASTEROIDS

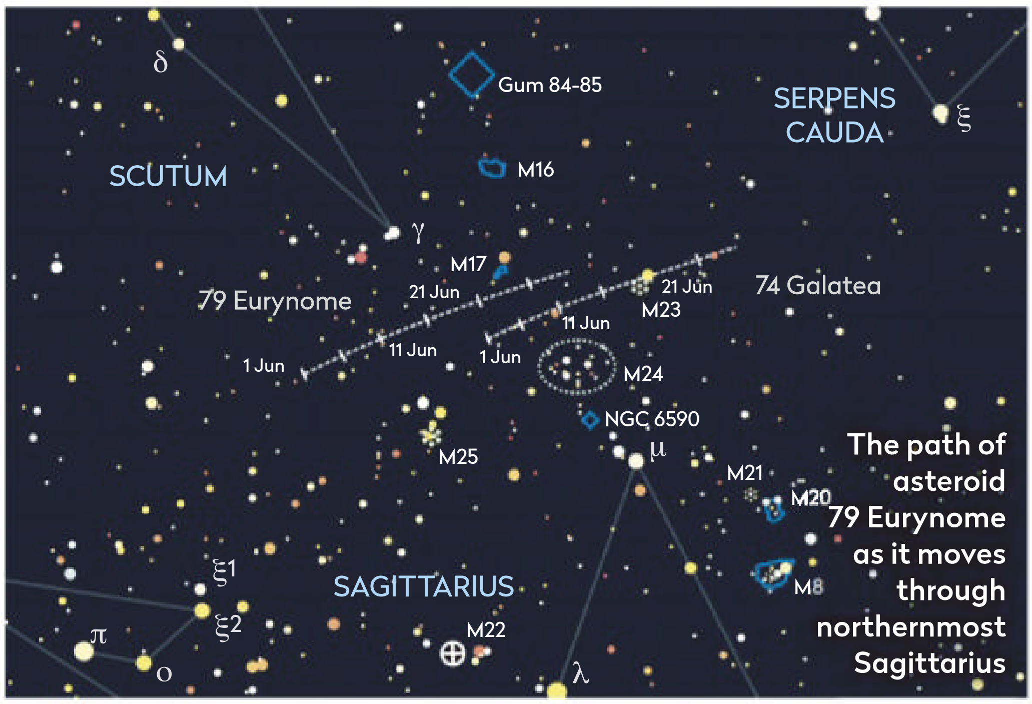
Asteroid 79 Eurynome provides a great imaging opportunity near the Swan Nebula

Asteroid 79 Eurynome will pose something of a challenge this month as it passes across a part of the sky packed with faint background stars. The deep twilight of a June night will make locating this relatively faint object harder than it would be under dark skies. Eurynome begins June at mag. +12.1, brightening to mag. +11.5 by 30 June. It reaches opposition on 26 June.

Eurynome's June track takes it along the southern regions of Scutum, technically inside the extreme northern region of Sagittarius. As a bit of a treat – if you can identify and keep track of 79 Eurynome during June – towards the end of the month it tracks just south of the beautiful deep-sky object known as M17, the Swan Nebula. This will present a great opportunity to capture it in a deep-sky image. Asteroid 74 Galatea is also in the vicinity, tracking south and further west of Eurynome. Galatea is fainter at around the mag. +12.5 mark.

Physically, Eurynome is a fairly sizeable lump of rock measuring 67km across. It's a main belt asteroid, meaning that it orbits in the region between Mars and Jupiter. Its orbit takes it out from the Sun to 2.9 AU (434 million km) and in as close as 2 AU (299 million km). It's an S-type asteroid meaning it's composed of silicate rock and is relatively bright with an albedo of 26.2%. Albedo is a measure of how much incident light is reflected by a body. During oppositions Eurynome can reach mag. +9.35.

Eurynome was discovered by Canadian astronomer James Craig Watson on 14 September 1863. It's the primary member of a proposed asteroid family which includes over 40 such objects. An asteroid family shares similar orbital elements and could be fragments orginating from a larger body.



The path of asteroid 79 Eurynome as it moves through northernmost Sagittarius

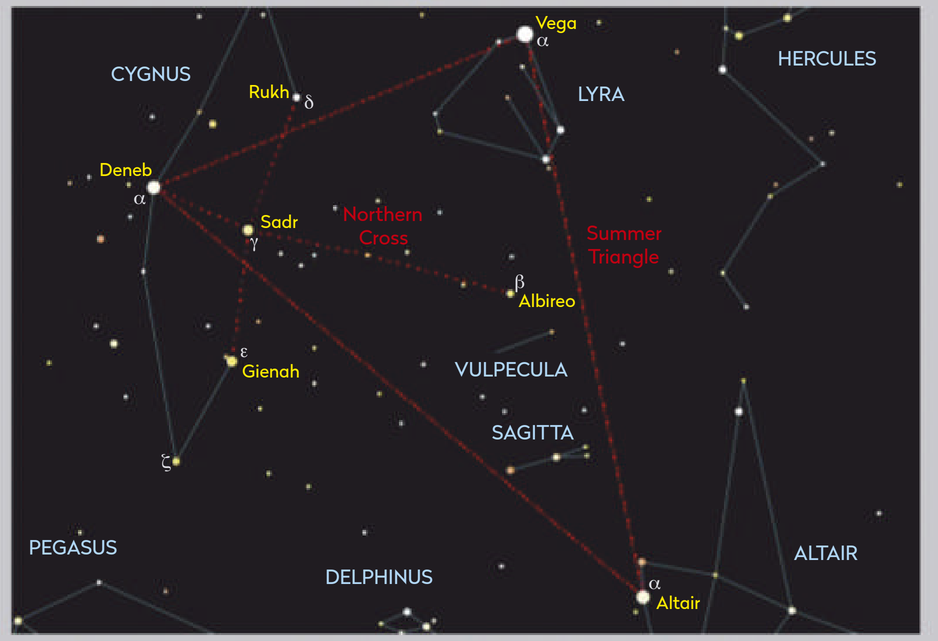
STAR OF THE MONTH

Deneb, one of the most luminous stars in the Galaxy

The star Deneb (Alpha (α) Cygni) is the faintest member of the asterism known as the Summer Triangle. It's also the northernmost star in the Northern Cross asterism, part of the constellation of Cygnus, the Swan. Despite the fact that both Altair and Vega appear to outshine it in the Summer Triangle, in reality Deneb is the brighter star. Its dimness is due to distance. While Vega is 25 lightyears away and Altair is 16.7 lightyears, Deneb is thought to be 2,600 lightyears. A blue-white supergiant star, Deneb has a spectral classification of A2 Ia. Despite ranking as the 19th brightest star, its great distance means that in reality it's one of the most luminous stars, possibly 196,000 times more so than the Sun. Deneb's size is estimated to be slightly greater than 200 solar diameters, with a mass in the range of 20 times greater than the Sun. Its magnitude varies from +1.21 to +1.29.

With a declination of 45° 17 minutes, Deneb appears circumpolar from the UK, just managing to pass above the northern horizon when it's at its lowest point, due north. Due to axial precession, the north celestial pole, which currently lies close to Polaris (Alpha (α) Ursae Minoris) will sit about 7° from Deneb in the period around 9800 AD.

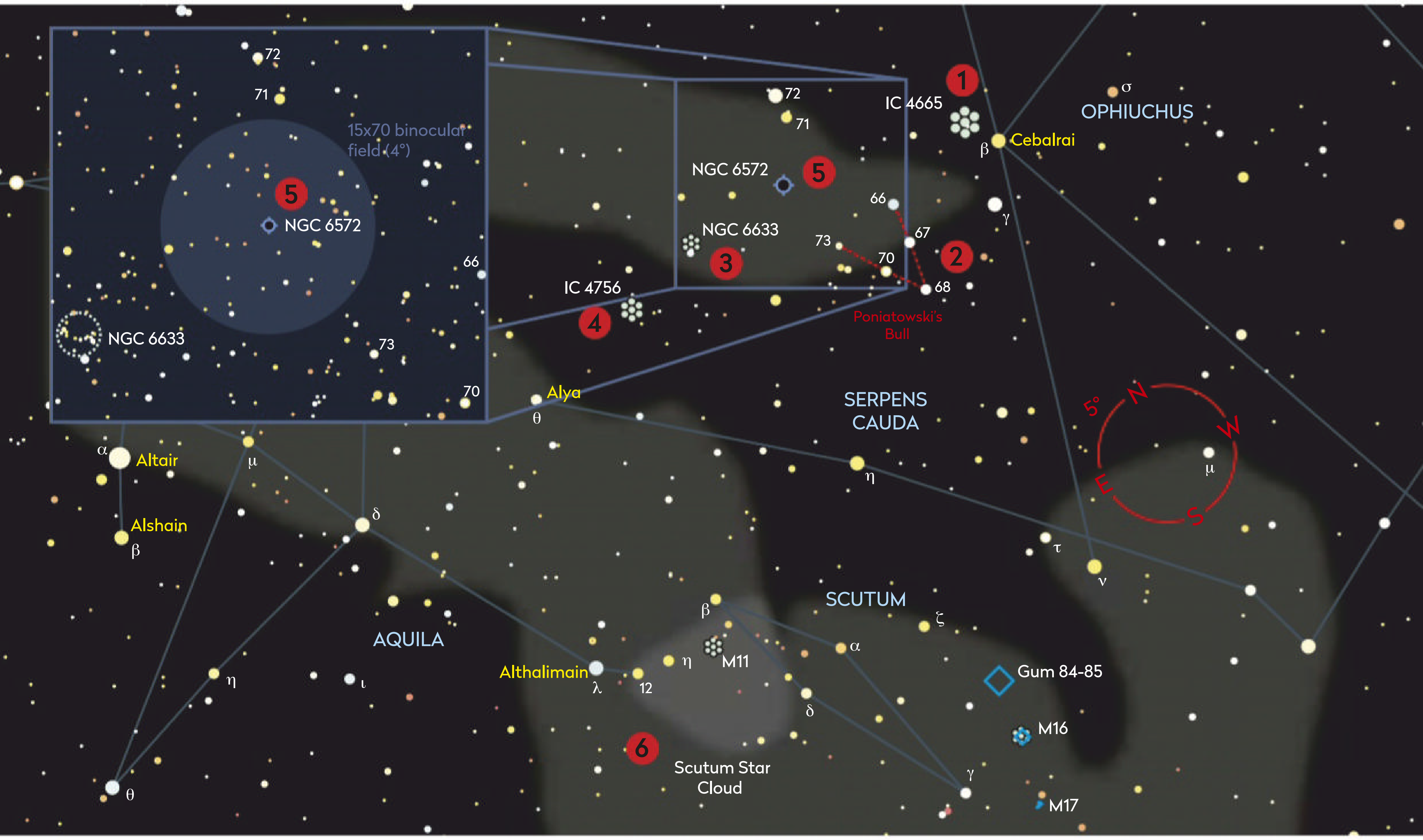
Deneb rides high across the sky in summer, its prominence enhanced by being a key point in two prominent asterisms. Deneb means tail and this is the part of Cygnus the star is supposed to represent.



▲ Deneb, a member of the Summner Triangle and the Northern Cross

BINOCULAR TOUR With Stephen Tonkin

V-shaped star clusters and rich star fields are among June's wide-field highlights



1 The Summer Beehive (10x50)

10x 50 The Summer Beehive (IC 4665), looking like a smaller version of Praesepe (the Beehive Cluster), welcomes you to the summer skies: look for the curved chain of white stars which forms part of the letter 'H' of the inverted word 'HI'. This large young (40 million years old) cluster is delightful in binoculars of any size. You should be able to resolve a dozen stars with a pair of 10x50s. ☐ **SEEN IT**

2 Poniatowski's Bull (10x50)

10x 50 We'll continue with another easy object; one that is better in wide-field binoculars than any other instrument. Poniatowski's Bull (Melotte 186) is a 4° diameter open cluster that includes the V-shape formed by 66, 67, 68, 70 and 73 Ophiuchi. These 4th and 5th magnitude stars lend it a similarity to the Hyades cluster in Taurus, hence its common name, given in honour of an 18th-century king of Poland. ☐ **SEEN IT**

3 NGC 6633 (10x50)

10x 50 If you follow the left-hand leg of the V-shaped asterism in from Mel 186 a further 5.5° to the northeast, you should find NGC 6633. This pretty cluster is easily visible in a pair of 10x50s with the four brightest stars shining against the 20 arcminute elongated glow of the unresolved fainter cluster stars. If you compare it to the Summer Beehive, you will see that its stars are yellower, and therefore older. ☐ **SEEN IT**

4 Graff's Cluster (10×50)

10x 50 From NGC 6633, pan 3° in the direction of mag. +4.6 Alya (Theta (θ) Serpentis), and find the 1° diameter soft glow of Graff's Cluster (IC 4756). This cluster is over 20 lightyears across and around 1,300 lightyears away. It rewards patient observation: try averted vision on it and you may experience it as being 'brighter stars, scattered over a background of diamond dust'. ☐ **SEEN IT**

5 NGC 6572 (15x70)

15x 70 NGC 6633 lies almost exactly between Graff's Cluster and this month's challenge, planetary nebula NGC 6572. At mag. +8.1, it's easily bright enough to be visible, but less easy to identify, so use the inset finder chart. Once you have identified it, see if you can detect any colour; you may detect a hint of green or blue (which colour appears to be age-dependent) with direct vision. ☐ **SEEN IT**

6 The Scutum Star Cloud (10x50)

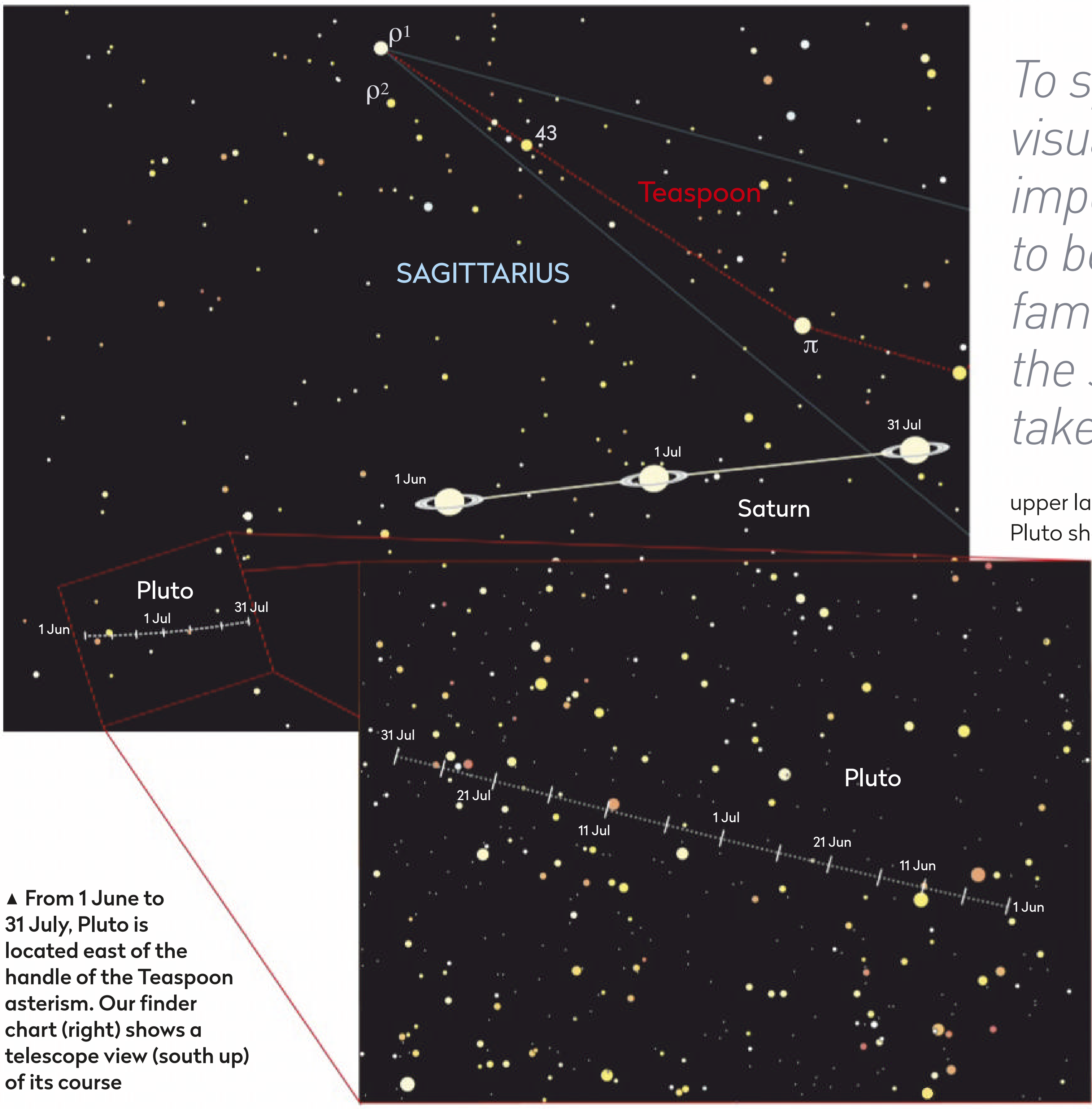
10x 50 Let's conclude with the rich star field that occupies the northeast quarter of Scutum. It's easy to find and has been mistaken for a cloud on a clear night. There seem to be ripples of stars, formed by the indistinct dark nebulae that weave through it. You should also see the stars that form the open cluster M11, called the 'Wild Duck' due to its V-shape. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

This month we hunt for Pluto, the Kuiper Belt object, both visually and with a camera



▲ **From 1 June to 31 July, Pluto is located east of the handle of the Teaspoon asterism. Our finder chart (right) shows a telescope view (south up) of its course**

To spot Pluto visually, it's important to become familiar with the star field, so take your time

It wasn't that long ago that observing Pluto was considered one of the harder challenges in amateur astronomy. However, modern camera sensors and larger affordable telescopes have helped progress things to the point where capturing an image of Pluto, at least, is now a relatively straightforward pastime.

Pluto is a Kuiper Belt object, orbiting mostly outside the orbit of Neptune. It has a diameter of 2,376km and thanks to the spectacular New Horizons flyby mission we now know a whole lot more about this enigmatic, distant world. From Earth, amateur telescopes will show it as nothing more than a faint speck of light around 14th magnitude. Just to add a little extra challenge into the mix, Pluto is currently moving against the rich star fields close to the centre of the Milky Way and from the UK at least, this places it in a very low part of the sky. Throughout June it is located in the region south and slightly east of the handle of the Teaspoon asterism in Sagittarius. Saturn is close too, off to the northwest of Pluto mid-month.

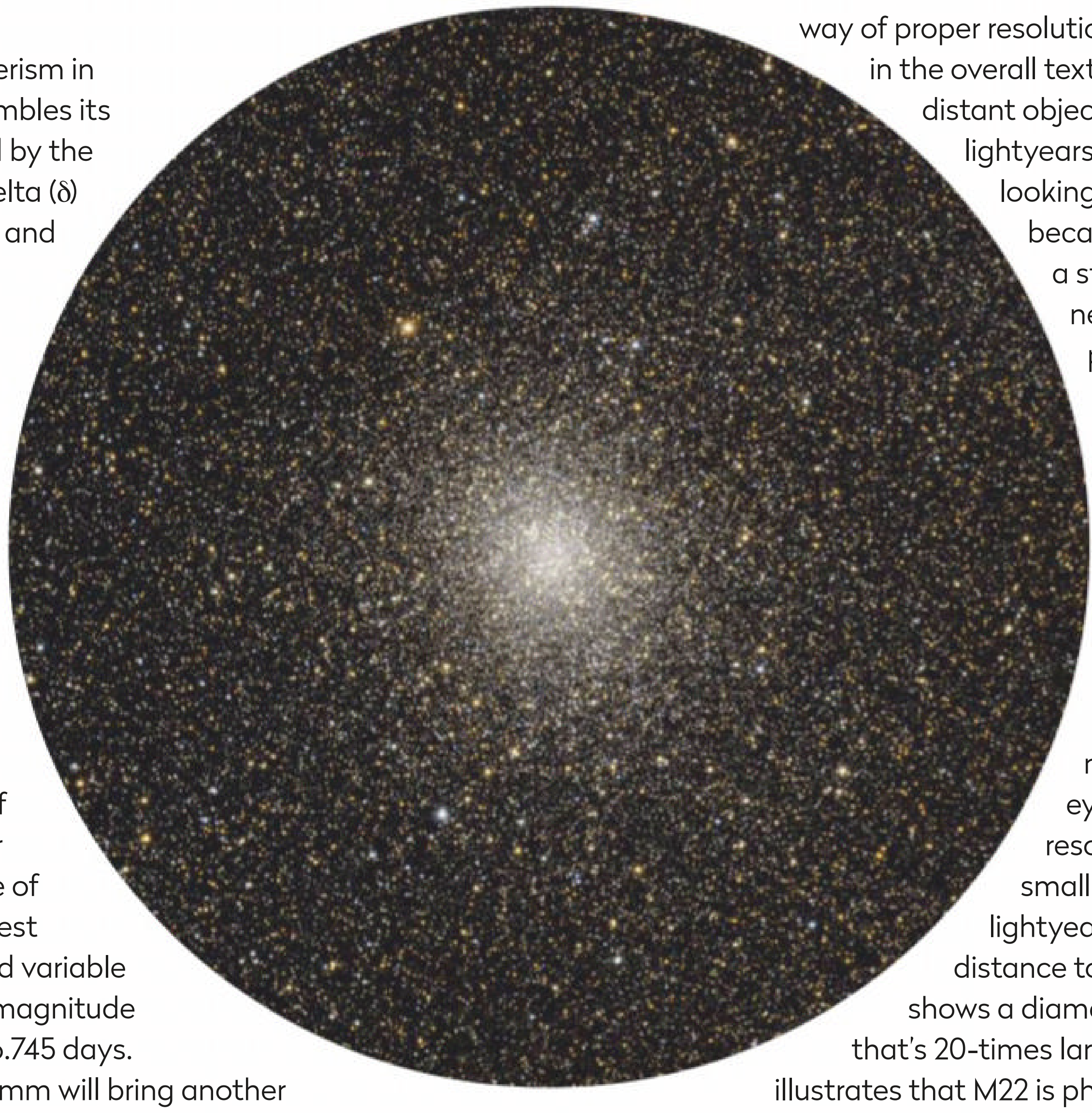
Imaging Pluto is relatively straightforward and can be achieved with a DSLR camera and a regular lens. We would recommend at least a 400mm lens for a good result although it should be possible to use shorter focal lengths too. The technique is simply to image the suspected field then wait a few days and repeat. Align both images in layer-based image editing software and toggle the upper layer's visibility on and off. Pluto should be visible because it moves. If you can't find it, you may not be imaging deep enough. The faintest stars you record should be at least mag. +15. A low to mid-range ISO is best because it will keep the noise (unwanted artefacts) down. Dark frame subtraction is highly recommended in order to remove false 'objects' from the frame.

Visually things are quite different. Looking through the eyepiece requires patience and dark skies – something that's not always easy to achieve at low altitude. A 300mm or larger aperture is normally recommended but bear in mind that respected observers have reported observation success with smaller instruments too. Positive sightings with 250mm scopes are not uncommon.

To spot Pluto visually, it's important to become familiar with the star field. Take your time here. Careful star hopping to the suspected field is the best way to do this. It may take a while to get this right on the first few attempts, but eventually, the field stars will become very familiar. Make sure you're properly dark adapted by spending at least 20 minutes in total darkness. Good hunting – and let us know if you succeed.

DEEP-SKY TOUR

From the Teapot asterism, via an enigmatic planetary nebula to M22, an impressive globular



▲ **M22 is a magnificent globular cluster, that is often obscured in murk near the southern horizon**

BERNHARD HUBL/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 M25

The Teapot is an asterism in Sagittarius that resembles its namesake. Its lid is formed by the stars Kaus Meridionalis (Delta (δ) Sagittarii), Phi (φ) Sagittarii and Kaus Borealis (Lambda (λ) Sagittarii), the latter marking the lid's pointed top. To locate the naked eye open cluster M25, extend a line from Delta through Lambda for the same distance again. From the point you arrive at move northwest by 1.7°. Through small instruments around 50 stars can be seen scattered over an area half a degree across. A brighter collection sits in the centre of the cluster, with the brightest member being the Cepheid variable U Sagittarii. This varies in magnitude between +6.4 to +7.0 over 6.745 days. Increasing aperture to 250mm will bring another 30 cluster stars into range. ☐ **SEEN IT**

2 NGC 6629

Moving closer to the Teapot's lid, located 2.2° north-northwest of Lambda is the 11th magnitude planetary nebula NGC 6629. This object is well defined but requires a decent magnification to see well. A 250mm instrument at 300x or higher is recommended to show the planetary's well-defined disc, which has an apparent diameter of around 15 arcseconds. NGC 6629 has a green colour which is evident at low powers. At high powers it's tricky to see any change in the uniformity of the disc brightness. The planetary's central star shines at mag. +12.8, which should be fine for medium to large scopes. ☐ **SEEN IT**

3 NGC 6642

Drop about one-quarter of a degree south from NGC 6629 and slew 1.5° east to reach our next target, the globular cluster NGC 6642. Here, a 150mm scope shows a 1 arcminute hazy glow but fails to resolve anything within the cluster itself. A 250mm scope improves on the view but there's still little in the way of proper resolution: just a hint of mottling in the overall texture of the cluster. It's a distant object estimated to be 26,400 lightyears away. Be careful when looking for it at low power because it's easy to mistake for a star. A 300mm scope is needed to begin the process of resolving the cluster stars convincingly. ☐ **SEEN IT**

4 M22

Head 1° east-southeast of NGC 6642 to the magnificent globular M22. Fifth magnitude M22 is a naked eye object and is easy to resolve, in part at least, using smaller instruments. It is 10,400 lightyears away, or 37% of the distance to NGC 6642. However, M22 shows a diameter of 20 arcminutes, that's 20-times larger than NGC 6642. This illustrates that M22 is physically much bigger. Larger instruments hint at a core elongation although the overall shape of the cluster remains circular. If M22 were high in the UK sky it would be greatly admired. However, it never really attains a good altitude for us and as a consequence battles the low atmospheric murk close to the southern horizon. ☐ **SEEN IT**.

5 NGC 6644

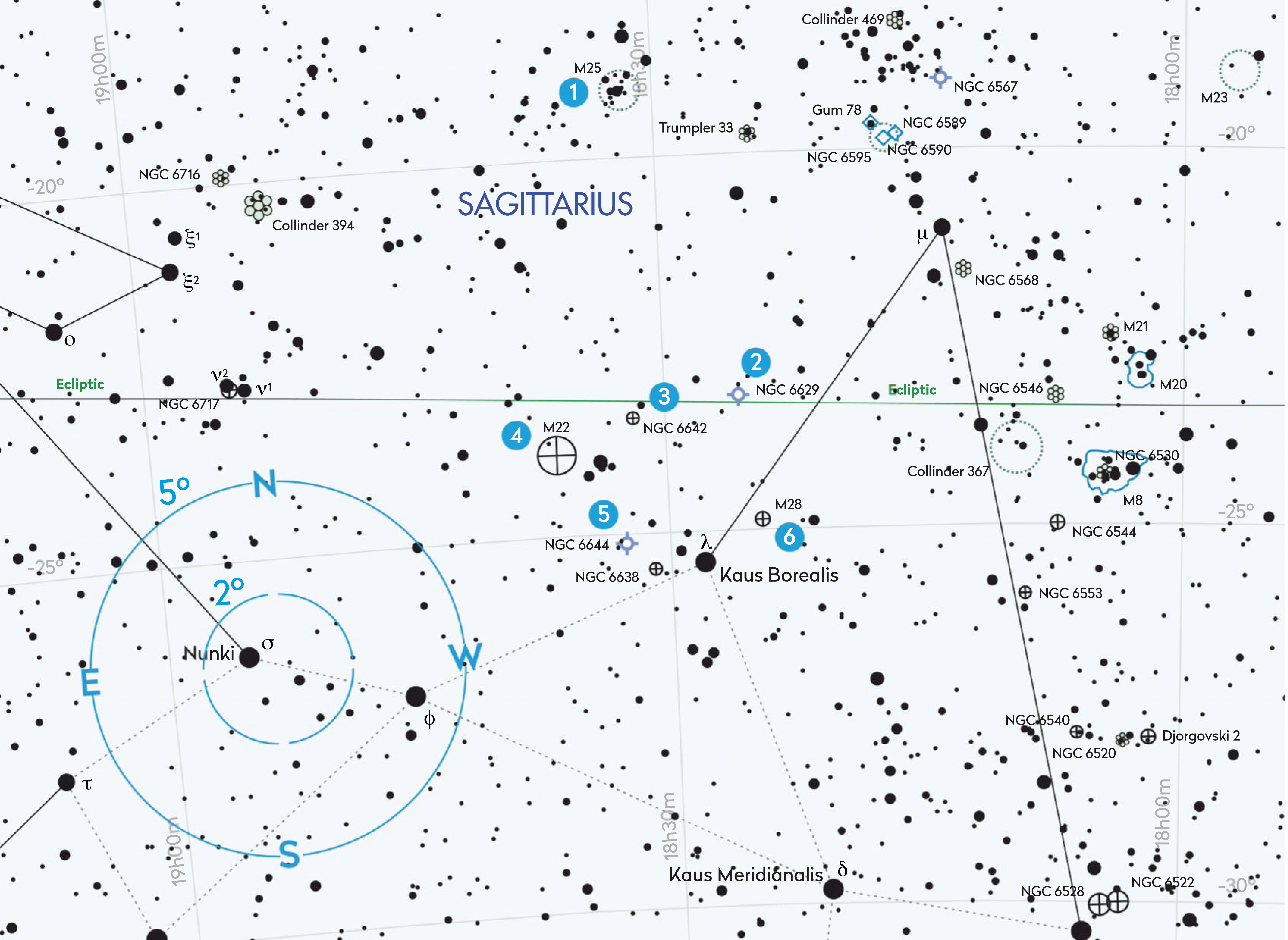
Next, head 1.4° southwest to reach the next target, NGC 6644, a planetary nebula 20 arcminutes north and 1° east of Lambda Sagittarii. This object is hard to discern as a planetary. It's mag. +9.7 and presents a tiny disc, just 2 arcseconds across, making it easy to mistake it for a star. NGC 6644 shows some colour, mostly described as green but some see it with a blue hint. It suits larger apertures but can be seen with smaller instruments. ☐ **SEEN IT**

6 M28

Our final target is easier to see than NGC 6644. M28 is a bright globular cluster located a fraction under 1° northwest of Lambda Sagittarii. It shines with an integrated magnitude of +6.8 and appears as a ragged-edged glow through a 150mm instrument. Larger apertures will begin the resolution process, starting with the stars at the outside of the cluster. A 250mm instrument shows an object 4-5 arcminutes in size with a core slightly less than half this size. M28 is estimated to be 17, 900 lightyears away and 12 billion years old. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More
ONLINE
Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**


SAGITTARIUS
19h00m
18h30m
18h00m
-20°
-25°
-30°
M25
M23
Collinder 469
NGC 6567
Gum 78
NGC 6589
NGC 6590
NGC 6595
Trumpler 33
NGC 6716
Collinder 394
ξ1
ξ2
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NGC 6568
M21
M20
Ecliptic
ν2
ν1
NGC 6717
NGC 6629
NGC 6642
NGC 6546
M22
Collinder 367
NGC 6530
M8
M28
NGC 6544
NGC 6644
NGC 6638
λ
Kaus Borealis
NGC 6553
5°
2°
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E
S
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Nunki
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τ
NGC 6540
NGC 6520
Djorgovski 2
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δ
NGC 6528
NGC 6522
1
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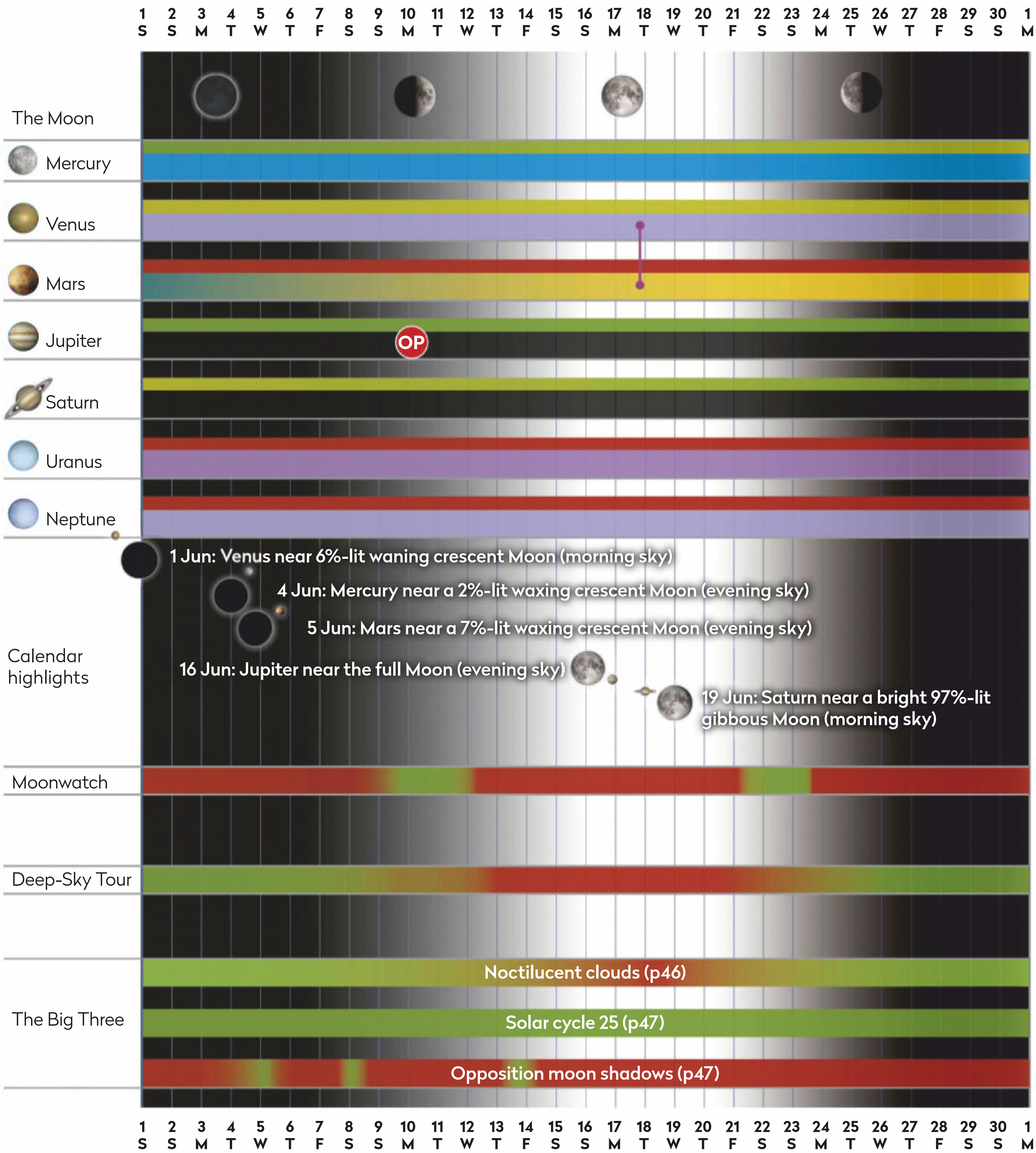
AT A GLANCE

How the Sky Guide events will appear in June



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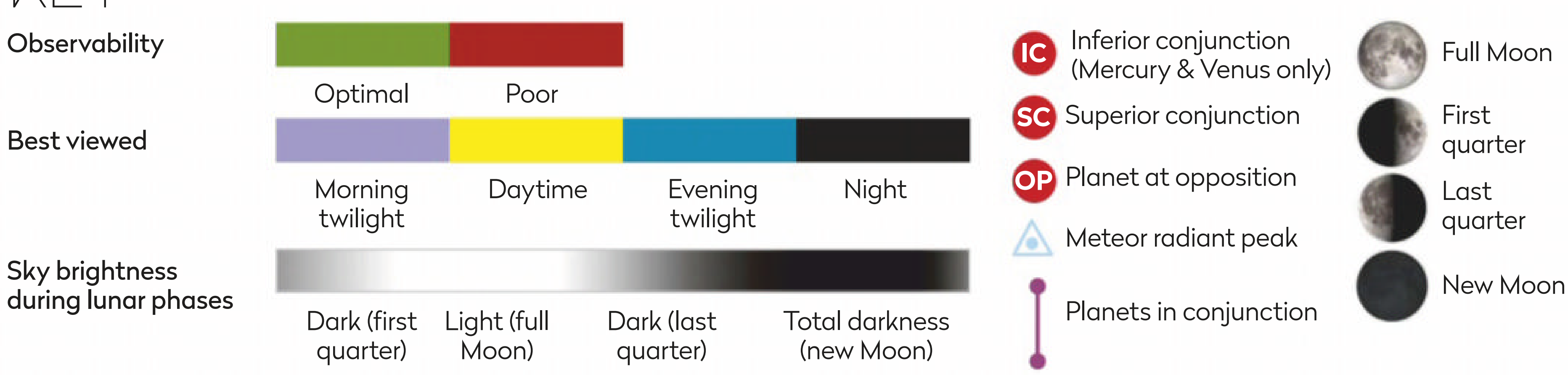


CHART BY PETE LAWRENCE

The fundamentals of astronomy for beginners

EXPLAINER

A guide to astro camping

How to prepare for an outdoor observing holiday

Many people look to combine camping holidays with astronomical pursuits. But how do you get the most out of the experience? There are lots of dark sky places across the UK and Ireland that actively promote stargazing. Many are in National Parks and Areas of Outstanding Natural Beauty, so you'll have plenty of scope to find a suitable campsite. A visit to darkskydiscovery.org.uk is a good place to start to find more information.

The nature of camping means many of these sites are located in ideal places that are situated well away from built-up, well-lit areas. You need a lack of street lamps and lights on the campsite, and a good view of the heavens with no (or at least limited) obstruction from buildings and trees. Talk with the management to make sure you are situated away from people who may get annoyed with you being up all night. Think about security and ask if there secure areas on site for locking your equipment away during the day, as a tent is not adequate protection against thieves.

Are you going to do visual astronomy, or nightscape or telescope astrophotography? For visual observing with a simple Dobsonian telescope or binoculars – or for nightscape astrophotography with a DSLR – no power is required and you can be up and running in minutes. With any powered telescope you will need a power supply. Some sites may have electric hook-ups; otherwise a portable power tank is the answer, such as the Sky-Watcher/Celestron PowerTank 17Ah. If you are staying for several days, you will need to consider the availability of re-charging facilities.

Once you have selected a camping area, you'll need to decide what to take. Always bring the least amount of equipment to get the job done. Carbon

▲ Getting away from it all: make sure you locate a campsite away from light pollution

JON HICKS, ARCH WHITE/ALAMY STOCK PHOTO

Where to pitch your tent

It's a good idea to find a campsite in or around a dark sky place. Visit www.darksky.org for a list of sites beyond the UK and Ireland.

ENGLAND
1 Bodmin Moor Dark Sky Landscape
2 Exmoor Dark Sky Reserve
3 Northumberland Dark Sky Park
4 South Downs Dark Sky Reserve

SCOTLAND
5 Galloway Forest Dark Sky Park
6 Coll Dark Sky Community
7 Moffat Dark Sky Community
8 Cairngorms Dark Sky Park

WALES
9 Elan Valley Dark Sky Park
10 Brecon Breacons Dark Sky Reserve
11 Snowdonia Dark Sky Reserve

IRELAND
12 Kerry Dark Sky Reserve
13 Mayo Dark Sky Park

◂ Top gear: Celestron PowerTank 17Ah (left), a Kendrick Stargate II observatory tent (below) and Explore Scientific ED APO 102mm refractor (bottom)

fibre telescopes like the Explore Scientific ED APO 102mm refractor are a great option, because you can use a smaller mount as the gear is not too heavy.

Reflective covers will help keep your telescope as cool as possible during the day. TS-Optics have a range in different sizes, but there are many kinds available on the market. Select a cover that ties tightly at the bottom.

Pitch perfect

If you're really serious about astro camping, the luxury option is an observatory tent. These have a removable roof, allowing the telescope access to the night sky. The Kendrick Stargate II is a good example and will give you an idea of what to look out for when you come to select your own. If you just want to naked-eye stargaze then an inflatable bubble tent is a great option. Make sure that your tents are fitted and erected correctly as they can become like kites in strong gusts of wind, your prized telescope with them.

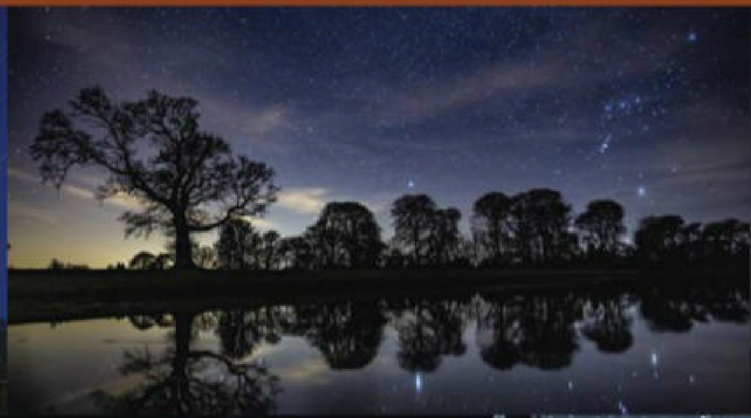
Think about some waterproof flooring – padding where possible, or even just a beach towel – as this will reduce dew from damp grass and protect any equipment that you might drop. A 12V hair dryer or dew heater for your telescope is a good idea: Astrozap makes a range of dew heaters suitable for different sizes of scope. You'll also need a lens cleaner and cloth to clean optics that have been dirtied by dewing or dust in windy conditions. Baader make cleaning fluid and cloths that do the job nicely. A red torch is also a necessity, as white light will interfere with your eye's dark adaptation, as is a set of tools for adjusting or tightening your scope setup. Smartphones can provide star chart apps and are useful in case an emergency arises. You'll also need an observing chair like the Sky-Watcher anti-tip observing chair, and a small foldable camping table for accessories; preferably with compartments for holding small pieces of kit together.

It goes without saying that you should bring warm clothes, especially for winter camping. There are many hand warmers and astronomers' gloves on the market, and army surplus stores can be good for picking up a heated flying suit – a great accessory for cold weather.

But, above all else, enjoy the experience; you may be rewarded with some spectacular discoveries.

Peter Williamson is an organiser of the annual Solarsphere star camp
Jonathen Harty is chairman of North Wales Astronomical Society

Stunning open moorland, dramatic upland dales and views that stretch for miles make Durham the ideal destination for a stargazing break.



The North Pennines Area of Outstanding Natural Beauty and UNESCO Global Geopark is the darkest mainland AONB in the country, and home to 16 Dark Sky Discovery Sites – more than any other part of the UK. Feast your eyes on up to 2,000 stars at any one time, including the Milky Way, and marvel at amazing objects millions of light years away.

The North Pennines Stargazing Festival, 23 October to 3 November, is the perfect opportunity, whether you're a newcomer or seasoned stargazer, to celebrate the incredible night skies and enjoy jaw-dropping stargazing opportunities and exciting events.

And as night turns to day, explore Durham's great outdoors on two feet or two wheels.

The Durham Dales, part of the North Pennines AONB, have inspired artists and writers through the ages with its wild open moors, hills, valleys, meandering rivers and picturesque market towns. Home to the mighty High Force waterfall, one of the most spectacular in England.

Explore 2,000 hectares of woodland in Hamsterley Forest, where you'll find some of the best off-road cycling tracks in the UK amongst 33 miles of waymarked trails, plus walking trails for all the family to enjoy.

Recognised internationally for its rare plants and wildlife, the Durham Heritage Coast is a 'must-visit' for nature lovers. Head off along the 11 mile coastal footpath for dramatic views across the North Sea coastline.

And when it's time to refuel look out for the Taste Durham mark, a sign of great food and service.

'Dark Sky Friendly' places to stay are waiting to welcome stargazers, providing information about stargazing and where to visit, flexible access times, with some even providing all the equipment you need to discover Durham's night skies.

Image credits – Killhope and Raby Castle Lake © Gary Lintern, Rookhope Arch and The Bowes Museum.

this is wild this is durham

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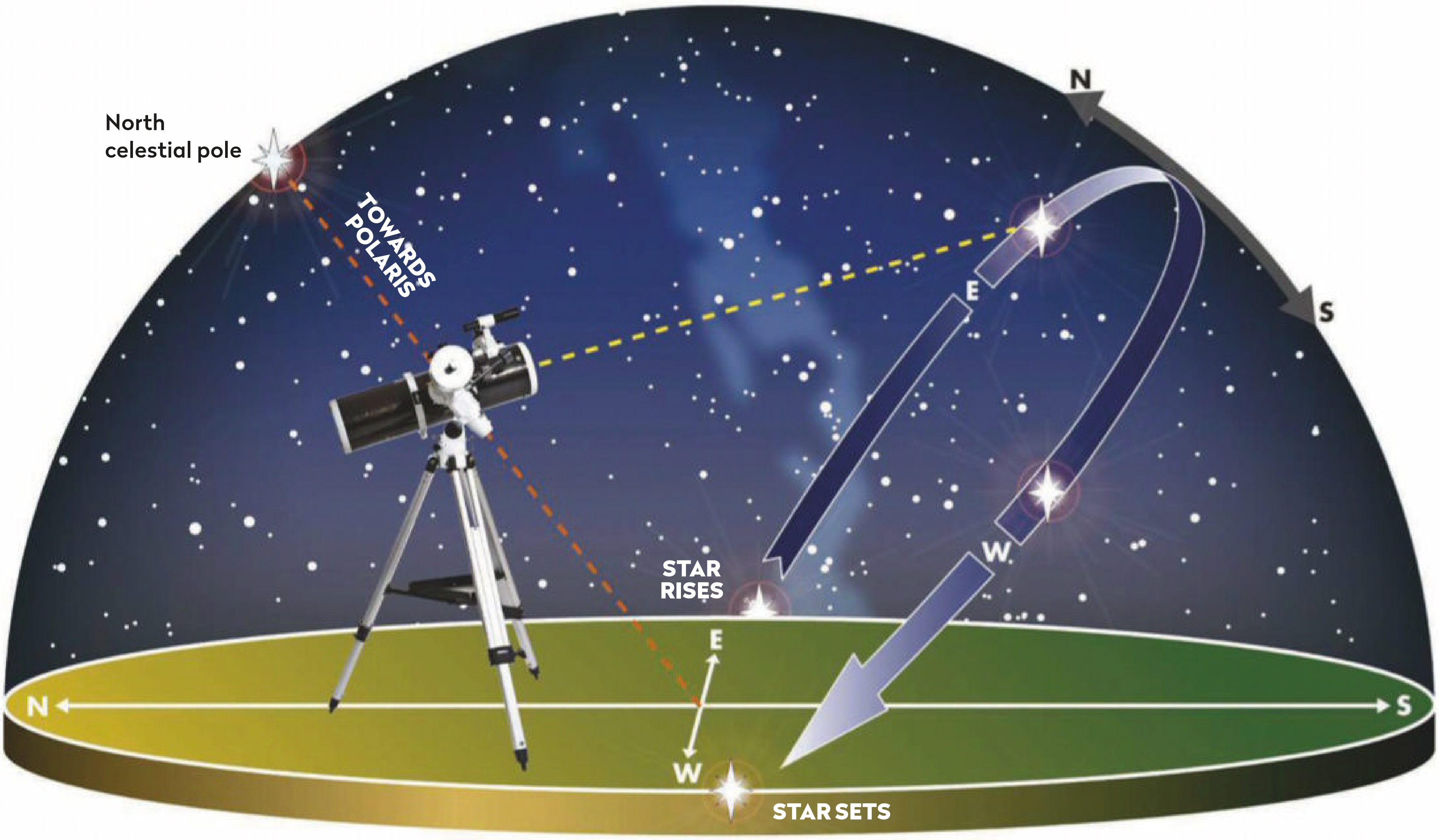
A buyer's guide to TELESCOPES

PART 3: Getting the best from your equipment

In the final part of our guide, **Tim Jardine** reveals how to maximise the potential of your new astronomy gear

PANTHER MEDIA GMBH/ALAMY STOCK PHOTO

A few simple set-up tricks and viewing techniques will help you get the most out of your telescope



▲ **Aligned on the north celestial pole, an equatorial mount makes it easy to track stars as they move from east to west through the night**

Setting up a telescope for the first time can be a daunting experience, but with a bit of practice and a little know-how, it will soon become second nature. Dealing with the telescope tube is straightforward enough and even if yours is a reflector or Cassegrain that has adjustable collimation, it's best not to tinker with it until you gain more experience. But the next vital element of your setup is the mount, the part that actually holds the telescope. All mounts do the same basic job – they point the scope at your chosen target – and there are two types: altitude-azimuth (often abbreviated to 'altaz') and equatorial.

Altaz mounts have two axes of rotation: one is vertical, allowing the scope to spin clockwise or anticlockwise; the other horizontal, so that it can be elevated towards an upright position. Dobsonian telescopes are the most basic form of altaz mount: a rotating base connected to a tilting tube. Like their tripod-mounted counterparts, Dobsonians don't need to be aligned with the sky or pointed in any particular direction. If your altaz mount or Dobsonian telescope has electronic Go-To capability, it will point automatically at whichever night-sky target you choose. But devices with this capability will need to be aligned to a particular object before use, so a list of targets is usually included in the device's instructions to help you do this. Consulting an astronomy app such as Stellarium or SkySafari can also be useful.

Although similar to altaz mounts, equatorial mounts have one axis that's parallel to Earth's axis of rotation, enabling the telescope to track the apparent movement of stars across the sky. This avoids you having to constantly nudge your scope as your target drifts out of view and is useful in astrophotography for capturing long exposures. In the Northern Hemisphere, we have a convenient star located almost at the point around which the night sky appears to rotate: Polaris, or the 'pole star'. This is the star you'll use to align your equatorial mount. You should find all the info you need in your mount's manual, alternatively check out our online guide at www.skyatnightmagazine.com/astronomy-how-set-up-equatorial-mount.

► **Dobsonian telescopes sit on relatively basic altaz (altitude-azimuth) mounts**

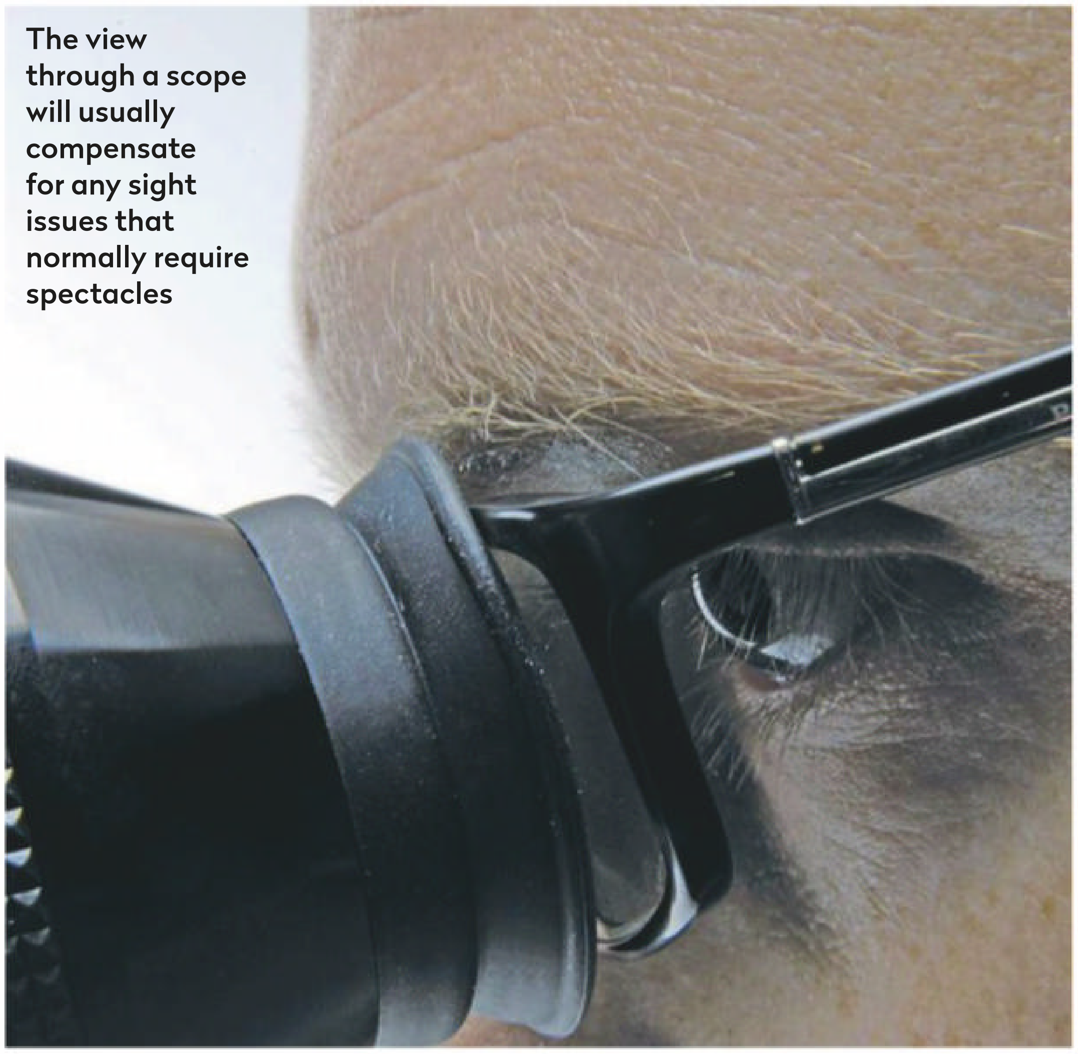
Which eyepiece?

Telescopes collect light, but it is the eyepiece that delivers it to your eye. Your choice of eyepiece will determine the magnification and field of view your telescope can offer. Most new telescopes come with an eyepiece, but eventually you'll want another one to give you more viewing options.

The first consideration when you're weighing up which eyepeice to buy is barrel size: either 1.25-inch or 2-inch. The larger of these, if compatible with your focuser, may give you a wider view, but is more expensive and can be heavy to use.

Eyepieces are classified by their focal length, which will be marked on them in millimetres. The smaller the number, the greater the magnifying effect on the view. There is little point in overdoing things, however, as there is a limit, known as 'useful magnification',

ILLUSTRATION BY STEVE MARSH, PAUL WHITFIELD X 4, WWW.SECRETSTUDI.NET



The view through a scope will usually compensate for any sight issues that normally require spectacles

There is little point in overdoing things, however, as there is a limit, known as 'useful magnification', beyond which the view starts to deteriorate

beyond which the view starts to deteriorate. A handy rule of thumb is to double the diameter of your telescope lens or main mirror, in millimetres, to give a figure indicating the maximum useful magnification for your telescope. If the telescope has a 100mm lens at the front, eyepieces giving a magnification up to 200x could be considered. For general observing, much lower magnifications usually provide a better view and make locating targets easier, although if sky conditions allow, pushing the limits a bit when observing planets can be advantageous.

It is also worth considering the apparent field of view that eyepieces provide, which is normally expressed in degrees. Wide-field eyepieces can be on the expensive side but provide especially immersive views. It is useful to try out a range of eyepieces before you make a purchase to determine the most comfortable and practical. You'll find that there ▸

An eyepiece for detail

A new eyepiece is a good first step in improving the view of your telescope and there are models to suit different needs and budgets

High power

Short focal length eyepieces like this Baader Hyperion 5mm offer higher magnification. This is great for viewing planets and smaller objects. Look for multi-coated lenses when choosing eyepieces.

£97 • www.firstlightoptics.com

Wide angle

The 100° apparent field eyepieces reveal galaxies in their surrounding context (and are easier to use with averted vision). The 2-inch Explore Scientific range offers value for money options.

From £267 • www.telescopehouse.com

Zoom eyepieces

Zoom models have an adjustable focal length for changing magnification without swapping eyepieces. The Meade S4000 Zoom goes from 8–24mm – ideal for most observing situations.

£79 • www.rothervalley optics.co.uk

Eyepiece sets

Eyepiece families share characteristics across focal lengths. The 1.25-inch Tele Vue DeLite range is lightweight and works with astigmatism correctors, so you can use them without spectacles.

£244 each • www.widescreen-centre.co.uk

▸ Practise setting up your scope while it's still light, and always try to observe across a clear horizon

▸ is usually no need to wear spectacles, however observers with astigmatism may require them, or else choose eyepieces that accept extra lenses to correct the condition.

Tricks and tips

Once you are familiar with your equipment, there are a few things you can do that will help you make the most of clear nights. Practise setting up your scope in daylight. Choose a spot that will be darkest at night with a firm, level base and unobstructed views to the north and south. Be aware that views over houses can be affected by shimmering warm air currents rising from below, while a sudden light from a window could ruin your eyes' adaptation to the dark, which can take around 30 minutes to set in. If your chosen spot is affected by stray lights, it might be possible to carry smaller Dobsonian or lightweight altaz telescopes to a better location during a stargazing session, but moving an equatorial mount without dismantling it first is not recommended.

Alongside the few really bright objects in the night sky, there are thousands of fainter ones, such as star clusters, galaxies and planetary nebulae. But even if your telescope mount has a Go-To capability, it can be tricky to spot them. With experience, picking out

ISTOCK X 3, PETE LAWRENCE, NASA/ESA AND ALLISON LOLL/JEFF HESTER (ARIZONA STATE UNIVERSITY). ACKNOWLEDGEMENT: DAVIDE DE MARTIN (ESA/HUBBLE)

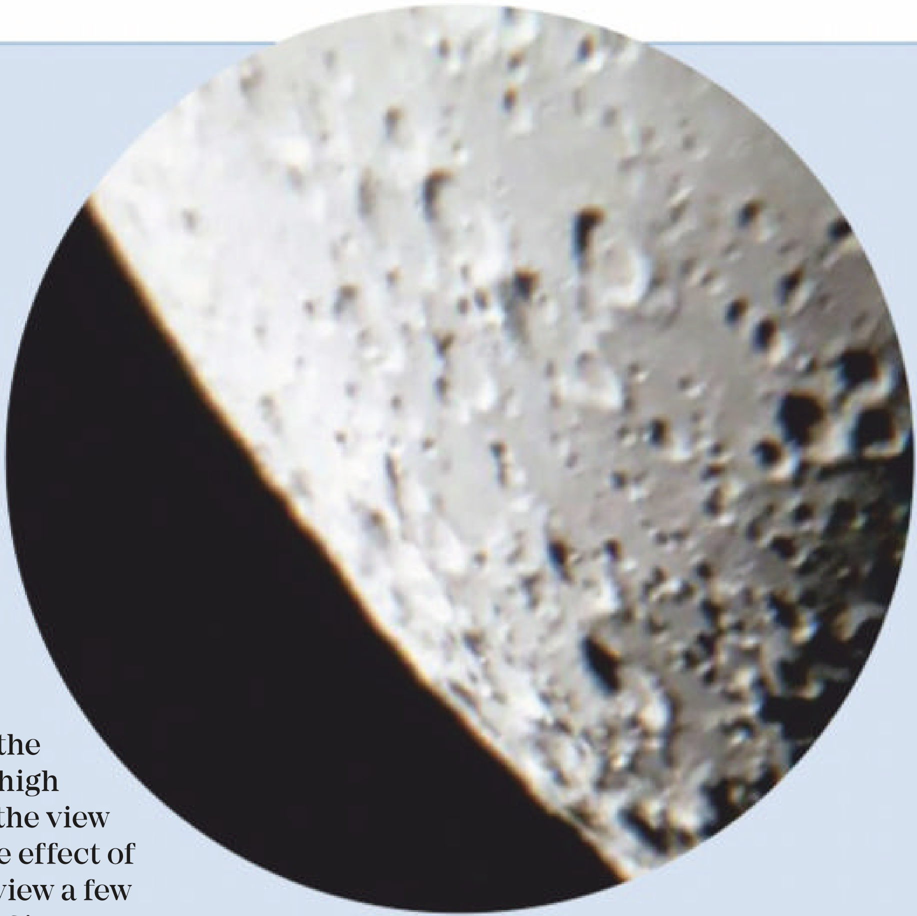
Clear skies?

You can't control the weather, but by being aware of what's occurring in the atmosphere you can prepare for the night ahead

The sky often looks ideal for stargazing, but looks can be deceiving. Amateur observers describe viewing conditions using terms such as 'transparency' and 'seeing'. Transparency is straightforward: observing a sky with poor transparency is like trying to look through a dirty window, but in this case the dirt is high, in thin clouds, atmospheric dust or moisture, or even aircraft contrails.

Seeing describes how steady or turbulent the atmosphere is and it can be estimated by observing brighter stars with the naked eye. When the seeing is poor, stars appear to twinkle more. Weather forecasts for astronomers can be helpful for anticipating observing conditions (try en.sat24.com or www.clearoutside.com) – if good conditions coincide with a dark new Moon period, the view should be outstanding.

Ambient temperature also plays a role, which is why telescopes need time to acclimatise when you take them outside – allowing an hour of cooling before you start observing really helps. Even so, a target that looks poor one night may be spectacular the next. A worthwhile experiment is to observe a bright lunar limb (the visible 'edge' of the Moon) at high magnification and note how the view appears to wobble. This is the effect of the seeing. Lingering on the view a few minutes will reveal patches of improved seeing, letting more detail shine through. Experienced observers will take their time over each target and keep coming back to favourite objects over the years.



▲ Focus on the bright limb of the Moon to gauge how good or bad the 'seeing' is

faint objects becomes easier and there are a few tricks that will help. A popular one is averted vision. Rather than staring directly at an object in the eyepiece, looking just to the side of it uses your peripheral vision, which is more sensitive to faint light. Experimenting with averted vision on a target like the Crab Nebula, M1, will help determine what works best for you. Generally speaking, if you view with your left eye, you should avert your vision to the left of the object, and vice versa. Try this on areas of extended nebulosity, perhaps around the edges of the Orion Nebula or the North America Nebula in Cygnus.

Another useful trick for spotting fainter objects makes use of the fact that our eyes and brain more readily notice movement, rather than static things. Telescopes can be gently tapped to make the view wobble a bit, which makes it easier for your eye to pick out any structures. A good target for practising this might be the Cygnus Loop, a large supernova remnant with intricate wispy details.

In the dark, our retinas become more sensitive and our pupils dilate. This makes a remarkable difference to stargazing, but it can take about half an hour to happen and will be lost if your eyes are exposed to a light source. Mobile phones should be screened with red cellophane or turned to a dim, red setting. Some astronomers even resort to putting screens around their scopes to block out encroaching lights. Ensure your observing location is as dark as possible and allow your eyes to gradually adapt to the darkness.

A final practical tip is to make yourself as comfortable as possible. Being relaxed while you're observing means you'll enjoy the experience so much more, whereas getting cold, tired, hungry or otherwise distracted might put you off setting up your scope the next time the sky is clear. The key to success is good preparation – anticipate the night ahead and plan accordingly. It can be useful to have a list of your intended observing targets to hand as well, so the night has clear objectives.

Ultimately, the best way to get the most out of using your telescope is to get it out whenever the conditions are suitable for observing... As they say: practice makes perfect.

▲ Remember that a large amateur scope's view of the Crab Nebula, M1 (right) won't be as spectacular as an image captured by the Hubble Space Telescope (left)

Tim Jardine is an experienced amateur astronomer and astrophotographer

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build an astrolabe

A home-made version of an ancient astronomical tool that tracks celestial targets

◂ A completed astrolabe can be used to tell the time from the Sun and to discover which stars are in the sky

Tools and materials

▶ Marking-out tools (a ruler, square, compass and pencil), a fret saw or coping saw with a fine blade, drill and bits for M4 screws, a scalpel or sharp craft knife, files or sandpaper for smoothing.

▶ Three small sheets of MDF, approximately A4 size and about 3–6mm thick.

▶ Sundries include M4 x 20mm screws, an M4 Nylock nut and two washers, a metal ring (shower ring or similar), wood and craft glue.

▶ For the finish you will need some primer and spray paint – we chose gold – and some clear spray lacquer.

This month's project is an astrolabe; an ancient tool from the second century that was developed into sophisticated instruments by Muslim astronomers of the 8th and 9th centuries. An astrolabe performs many functions but only has a few components. Firstly, there is the 'mater' – the main disc of the instrument. We opted just to describe the mater front and its markings for this DIY article, but you may add the back and corresponding rulers in the future as you explore more functions.

The front of the mater has a grid and horizon, corresponding to your location (if you change location you need to change this grid). Around the edge is a fixed ring, which is marked with degrees and a 24-hour clock. Inside this ring there is a 'rete' – a sky map with significant stars indicated as well as a zodiac ring (a circle representing the path of the Sun over the year). The rete can be rotated in relation to the grid below just as the stars appear to rotate in the sky. Finally, there is the 'alidade' – a pointer that is used in conjunction with the outer ring. The alidade is also used for taking sightings of objects above the horizon (with the astrolabe suspended vertically). The alidade is sometimes mounted on the back with a simpler ruler on the front to indicate the time.

ALL PICTURES: MARK PARRISH

Mark Parrish is a bespoke designer. See more of his work on his website: buttondesigns.co.uk

More **ONLINE**

Download plans, diagrams and more photos for this project. See page 5 for instructions

Checking for accuracy

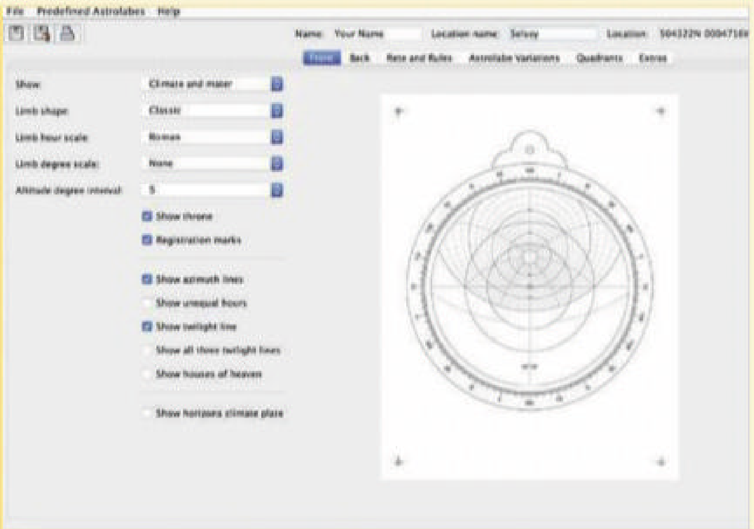
The geometry involved and accuracy required to make this instrument are beyond most of us, so we're grateful to Richard Wymarc for permission to link to his 'astrolabe generator', a Java-based app you can use to print out all the dials and markings required for a functioning instrument. His website, www.astrolabeproject.com, is where you'll find this along with a wealth of information about the astrolabe's history and uses.

Our design calls for some thin MDF on which to mount the printouts. We used veneered MDF from our scrap pile but plain MDF would be better. If you have a laser cutter you could use the CAD files to cut out the parts, but most of us will need to spend time with a fine-toothed fret saw. A board clamped to the work surface with a V-shaped cut-out similar to a jeweller's bench is great for supporting the fine 'spokes' of the rete when cutting. This is the fiddliest part of the job but, providing the star pointers and the zodiac ring are accurately cut, the supporting arms can 'deviate' a bit without affecting the function.

We sprayed the MDF and dusted the printouts with gold paint. Clear lacquer extends the life of the printed surfaces. We rolled a strip of aluminium for the ring that suspends the astrolabe when taking a sighting.

There isn't room here for instructions but we have described basic functions in our downloadable guide.

Step by step

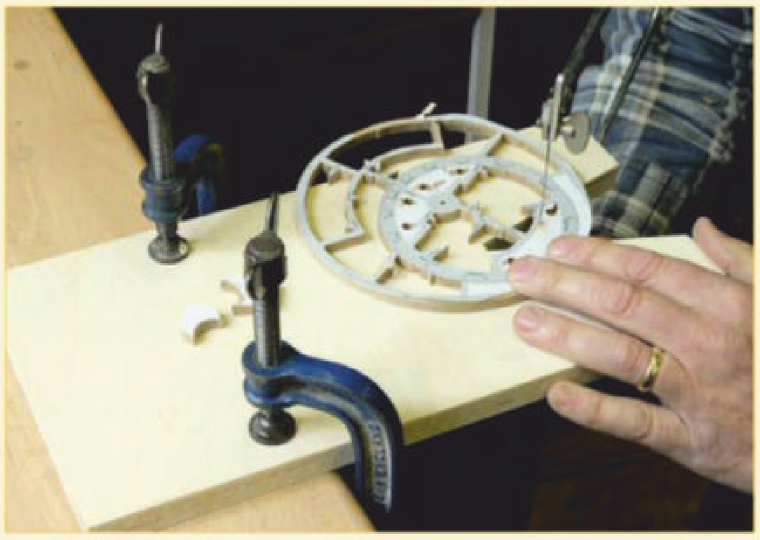


Step 1

Download the astrolabe generator program (astrolabeproject.com.) Input your location (the format is ddmmssN, dddmmssW where d = degrees, m = minutes, s = seconds) and print the dials and rulers required. Use a copy as a template for cutting out.

Step 2

Print off the downloadable plans and template. Check the measurements against your printed dials and mark out the MDF parts (the generator can produce different file types and sizes vary). The upper throne layer can be formed from the ring.



Step 3

Use your saw to cut out the parts. Drill a 4mm hole in the centre of the mater back and rete discs and join with temporary screws. Clamp the upper ring to the mater back and file and sand any high spots until the rete turns with no binding.

Step 4

Stick a paper copy of the rete to the rete disc. Drill holes in open areas through which you can pass the fine saw blade. Taking great care – especially around star pointers – cut out each part. Support the part you are cutting, or it may snap.

Step 5

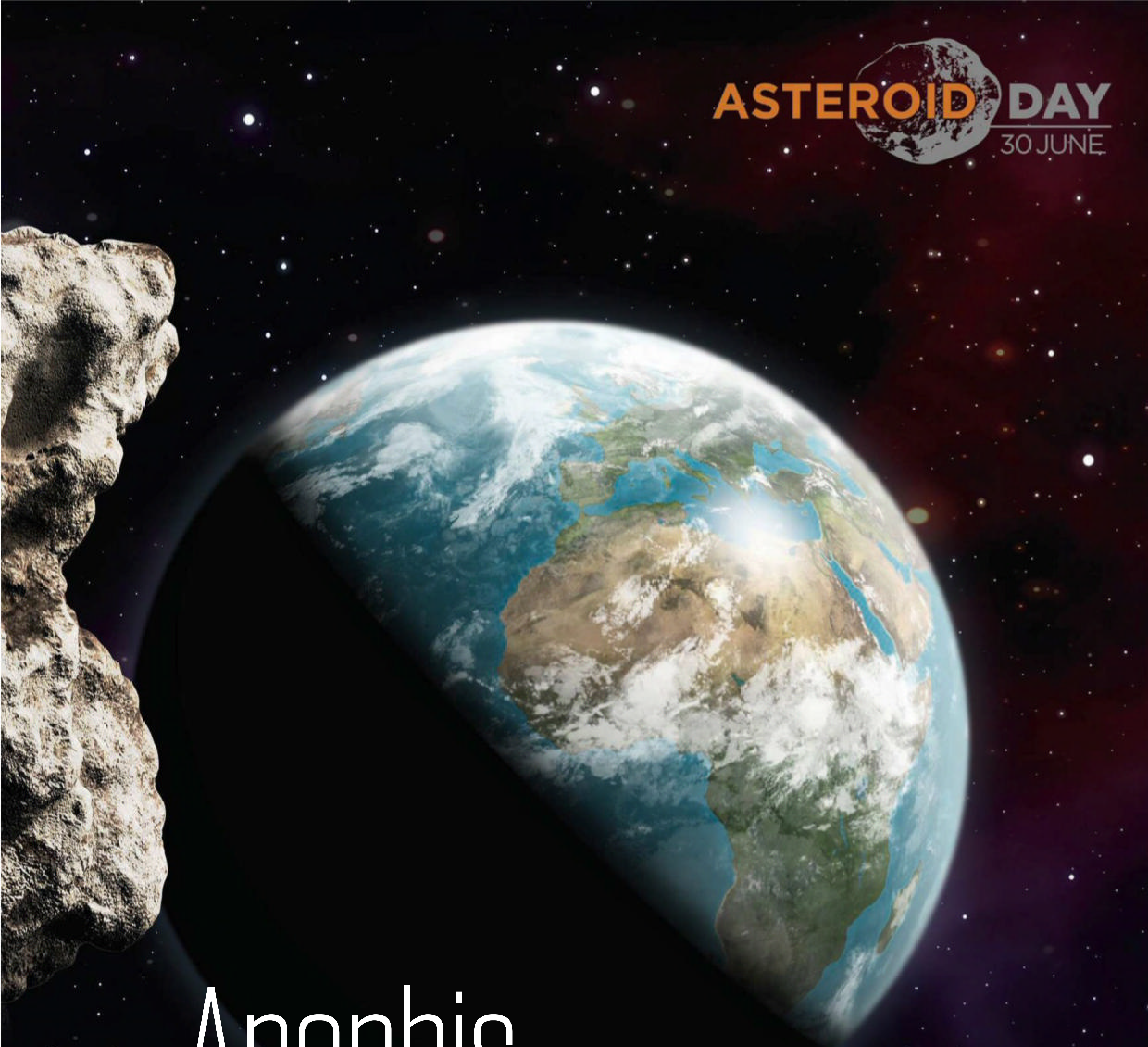
Cut small sighting blocks to add to the alidade. Glue these in place and glue the ring to the mater back. Make sure the ring fits round the rete before clamping. When the glue is dry, spray the parts with some primer and sand everything smooth.

Step 6

Decorate the astrolabe with spray paint. Cut round the printouts with a knife or scalpel. Glue on the trimmed rete, mater and ruler printouts. Finish off with clear lacquer, before assembling with a screw, placing a ring through the throne.

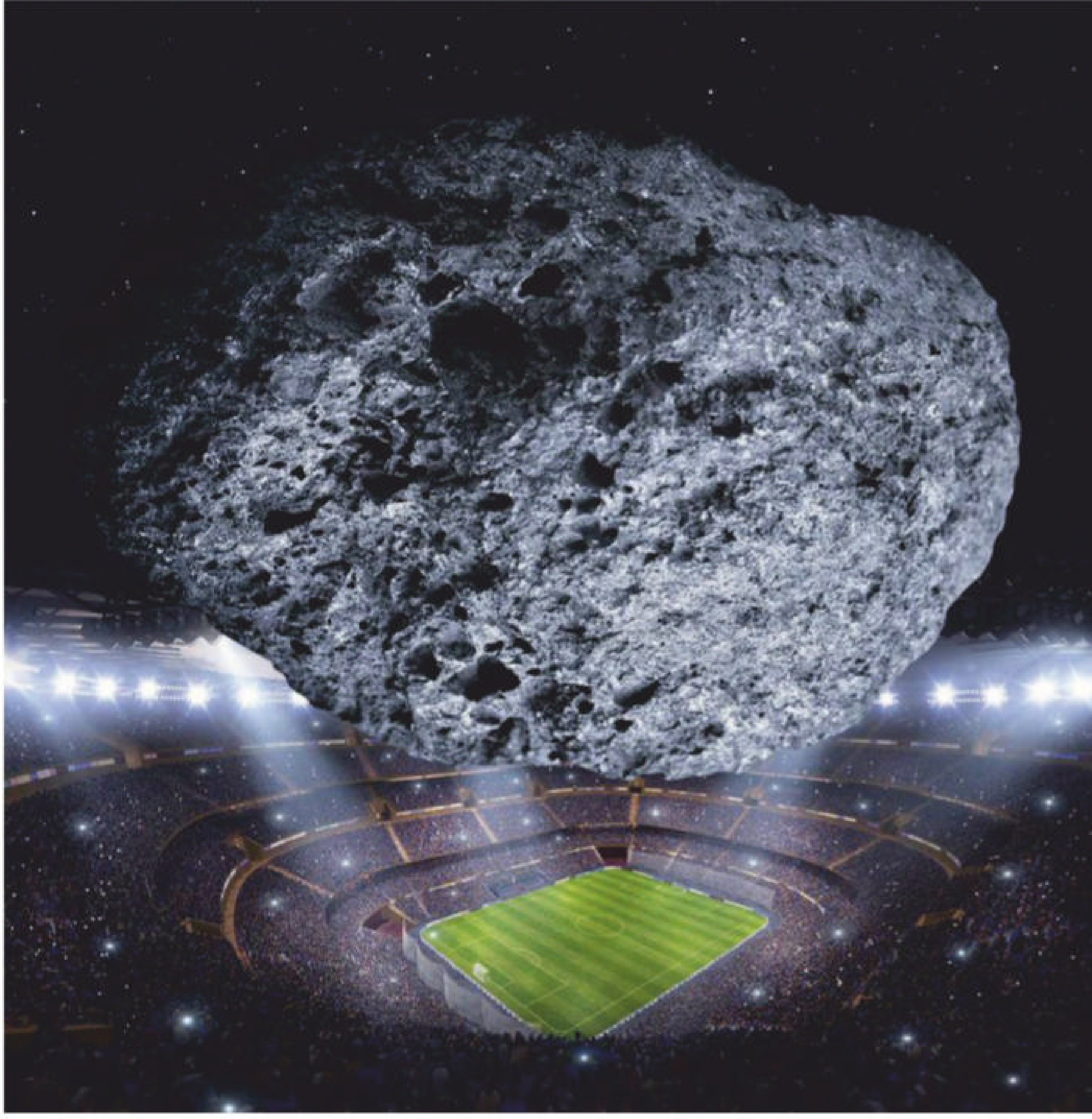
Sudden impact: we need to keep a watchful eye for threats from asteroids and other near-Earth objects

ISTOCK



Apophis APPROACHES

On Asteroid Day, 30 June, astronomers call on the world to do more about the planetoids which could wipe out human civilization. **Sandra Kropa** looks at why the task of tracking the threat presents experts with real challenges



Picture trying to find a needle in a haystack, knowing that needle has the potential to explode with the power of thousands of nuclear bombs – that's what searching for asteroids looks like. In 2004, one of these uninvited guests from outer space gave the world particular concern – asteroid Apophis. Initial reports predicted there was a 1 in 37 chance of the space rock hitting Earth in 2029. But a week later this possibility had dropped to practically nil. How did Apophis go from being one of the most dangerous asteroids ever discovered to suddenly being harmless? The answer lies in the way that space agencies track potential space rocks and how they predict their future paths.

When astronomers discovered Apophis in June 2004 they could only collect a very limited set of observations. Though the asteroid was the size of three-and-a-half football fields, it was difficult to observe it – the weather was poor, the full Moon was out and there were problems scheduling the telescopes. All considered, the timing of Apophis's discovery was unfortunate.

Initial calculations of the orbit of Apophis using this sparse data showed the probability of it impacting Earth during its next flyby on 13 April 2029 was very

▲ **It's not hard to imagine the potential damage an asteroid the size of Apophis could do**

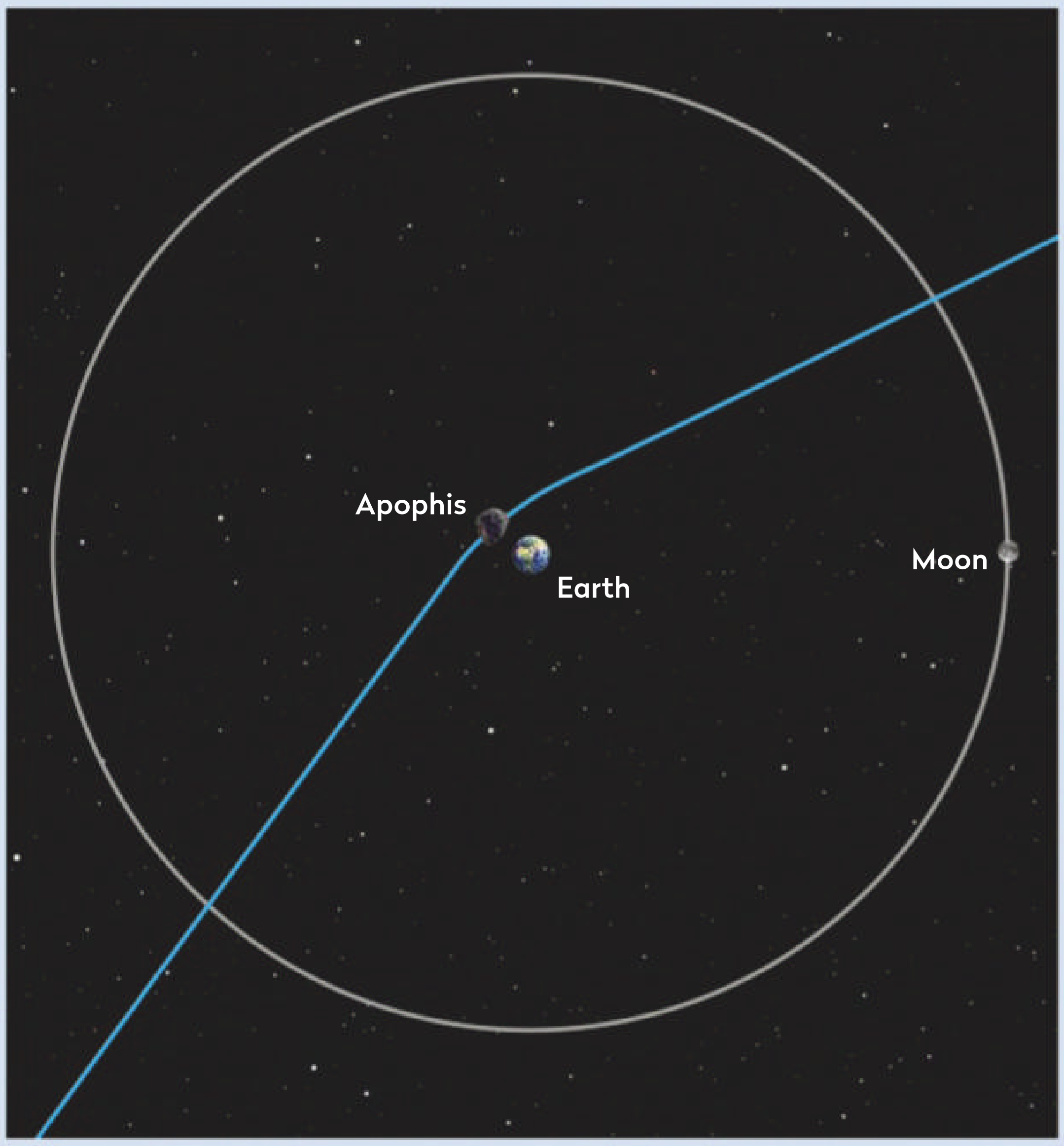
Getting to know APOPHIS

After over a decade of study, how much do we know about the menacing asteroid?

Apophis is a near-Earth asteroid whose orbit brings it relatively close to Earth. It's as Aten-type, or Earth-orbit crossing, asteroid. Based on radar images, astronomers estimate that it is roughly 450x170 metres in size – large enough to have a global effect if it did impact Earth.

Apophis is known as a chondrite, meaning the rock has never been part of a planet and remains mostly unchanged from the early era of the Solar System, containing minerals like olivine and pyroxene. It has a retrograde rotation, which increases the probability of impact with Earth in 2068. The asteroid has 12 potential impacts with Earth between 2060 and 2105. All of them are classified as Torino Scale 0 category, meaning they have low impact probability.

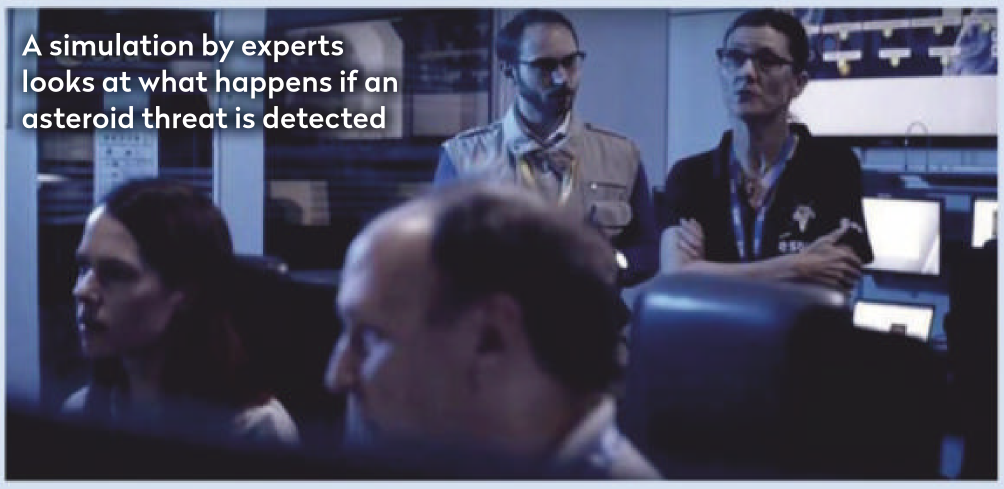
Apophis will approach Earth a few times in the next decades. Its predicted positions are very well determined up until April 2029, when the asteroid will pass about 31,000km from Earth's surface – 10 times closer than the Moon. This close approach is a rare event: on average an object the size of Apophis comes this close to Earth once every thousand years. During the encounter Apophis will even be visible with the naked eye under dark skies.



▲ **Apophis is predicted to pass just 31,000km from Earth in 2029, well inside the orbit of our Moon, in an event that occurs once in a thousand years**

Dodging DISASTER

We may be able to discover the threat from an asteroid but is there anything we could do to stop it endangering our planet?



A simulation by experts looks at what happens if an asteroid threat is detected

Knowing about an asteroid in advance is one thing, but what would happen if searches uncovered an asteroid that was about to impact Earth? To answer this question, a team of experts at the 2019 Planetary Defence Conference ran a five-day exercise back in May, simulating what would happen in the wake of the discovery of an (entirely fictional) asteroid heading towards Earth.

When the asteroid was first 'discovered', early observations predicted it had a 1 in 100 chance of Earth impact on 29 April 2027. But as the space rock was studied in more detail, they realised it was heading for Denver, Colorado and would hit with the force 30 times greater than the bomb that dropped on Hiroshima.

They now had a choice: deflect the asteroid, or evacuate the impact zone. The team opted to mount a redirect mission, firing a weight at the asteroid to knock it off course just enough to miss Earth. It worked, but in the process a large fragment broke off that was still on course for our planet, heading for New York – time to start planning for evacuation!

While this scenario was fictional, and intended to test the preparedness of international space agencies, there could come a day when similar decisions have to be made to save our planet from the impending threat of an asteroid.

high: 2.7 per cent or 1 in 37. Wanting more data, astronomers looked back at historical records.

"When Apophis was discovered in 2004, after a few nights of observations, we tried to find so-called 'recovery observations' and were able to find images of the night sky of March the same year, when the object was there, but not identified. This helped and gave us a three-month arc length to determine its orbit," says Juan Luis Cano, operations manager at ESA's Near-Earth Object Coordination Centre.

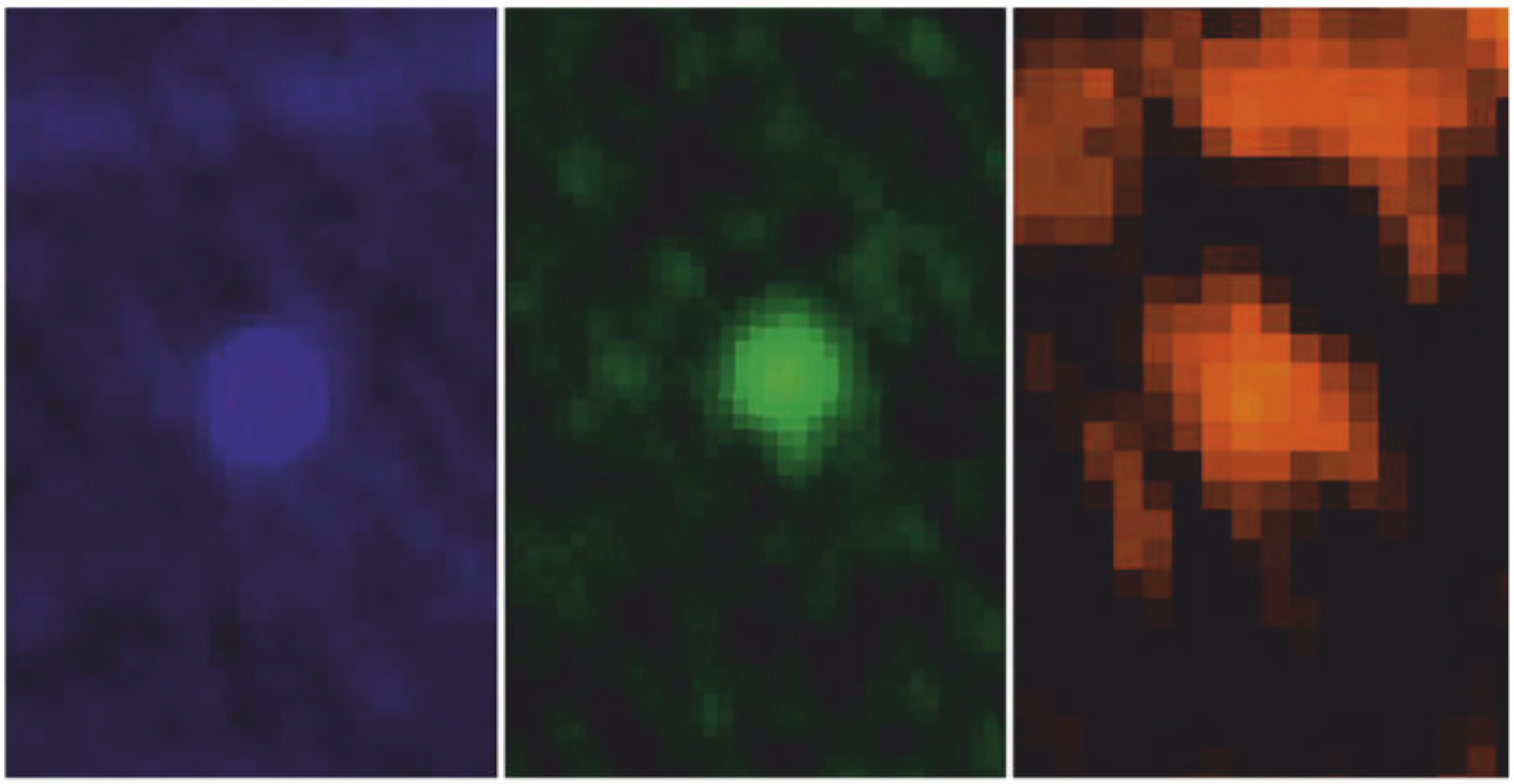
This finding was a crucial step in making further predictions about the path of Apophis, which determined there was practically zero chance of the asteroid impacting Earth in 2029. For some years, there remained an open question over the likelihood of Apophis's next flyby, in 2036, ending in an impact, until NASA ruled this possibility out as well. The next close pass after that is in 2068.

Watching the skies

Astronomers are currently surveying our Solar System, searching for all asteroids that might make a significant impact on Earth. But they are relatively small and dim objects which can be observed for limited periods of time while they are close to Earth. Most of the observation campaigns are performed by NASA asteroid surveys – such as The Catalina Sky Survey, Pan-STARRS and others that scan the night sky to spot the space rocks.

"On average every month 150 to 200 new near-Earth asteroids are discovered. In the past few years it's been 2,000 objects per year," says Cano.

Once a discovery has been confirmed by the Minor Planet Centre, word is sent around astronomers ►



► ESA's Herschel Space Observatory captured Apophis in 2013. The images show the asteroid pictured in different colour wavelengths

ISTOCK X 2, ESA/EUROPEAN SPACE AGENCY, ESA/HERSCHEL/PACS/MACH-11/MPE/B.ALTIERI (ESAC) AND C. KISS (KONKOLY OBSERVATORY)

▸ Recently visited by the OSIRIS-REx spacecraft, asteroid Bennu will pass Earth in 2032

Gauging THE RISK

There are many factors to consider when judging how dangerous an asteroid is

Though there are lists of asteroids considered a risk, so far none have been discovered with a score of more that zero on the Torino Scale within the next 100 years. The biggest risk in this window is asteroid 2010RF12, which risks impacting Earth in 2095. However, even if it did impact Earth (which is unlikely) it's only 9m in diameter. The next big concern is the much larger Asteroid 1979XB which is 900m across. Its highest impact risks are in 2056 and 2113, but even these are so low as to be considered nil.

There are only three large asteroids that have been discovered which might be of concern past this 100-year mark: Asteroid 29075 1950DA will approach our planet in 2032, but when it returns in 2880 there is the potential it might impact Earth. According to the analysis based on more than 500 observations since its discovery in 1950, there is 99.988 per cent chance that this asteroid will miss Earth.

Asteroid 101955 Bennu will approach Earth in 2037, with a small chance of impact in 2175. Asteroid 410777 has a higher possibility of impact in 2185, but the chance is still low at 0.14 per cent.

However, the fact that this risk list is so low does not mean we should be concerned. It just means that the asteroids we should be most worried about are the ones we have yet to discover.

▸ to track and follow up on the asteroid using telescopes around the world.

"At ESA we observe them by telescope from Tenerife, but when they become very faint, we need more powerful tools, so we collaborate with the Very Large Telescope in Chile and others that can track the objects and their position in the sky," says Cano.

After the follow up observations further orbital calculations determine if there's any risk of the new-found object ever hitting Earth.

Data and software tools help to calculate the trajectory of Near-Earth objects with quite a high accuracy, but just like any physical measurement, an asteroid tracking observation contains some degree of uncertainty, which filters through into the known orbit.

"The uncertainty of an asteroid's predicted position tends to increase over time, especially if it goes near a planet," says Davide Farnocchia, a navigation engineer at NASA's Jet Propulsion Laboratory who has studied Apophis. "Overall, our impact prediction capability depends on the precision of the observations, the length of time over which an asteroid has been tracked, and how much its path is affected by encounters with the planets."

Another aspect astronomers have to consider is how large an impact would be if it did happen. They can compute the energy of an impact as long as they know the impact velocity and the asteroid's mass. The first can be determined from the orbital motion of the asteroid, but the mass has to be inferred based on its brightness, as well as radar and spectral observations if they exist.

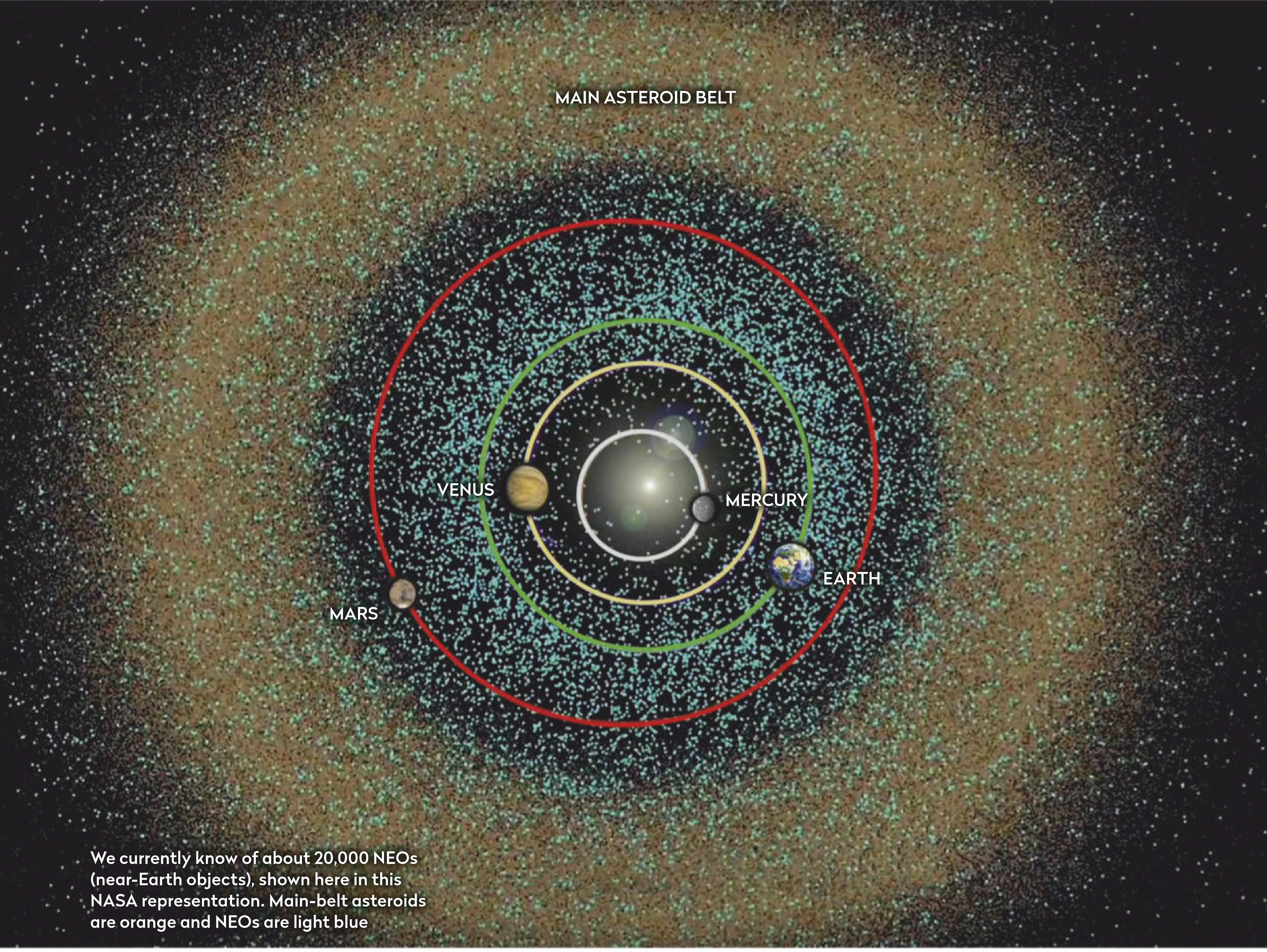
Any asteroids that are considered to have a reasonable risk of significant impact have their orbits forecast for the next hundred years

Risk assessment

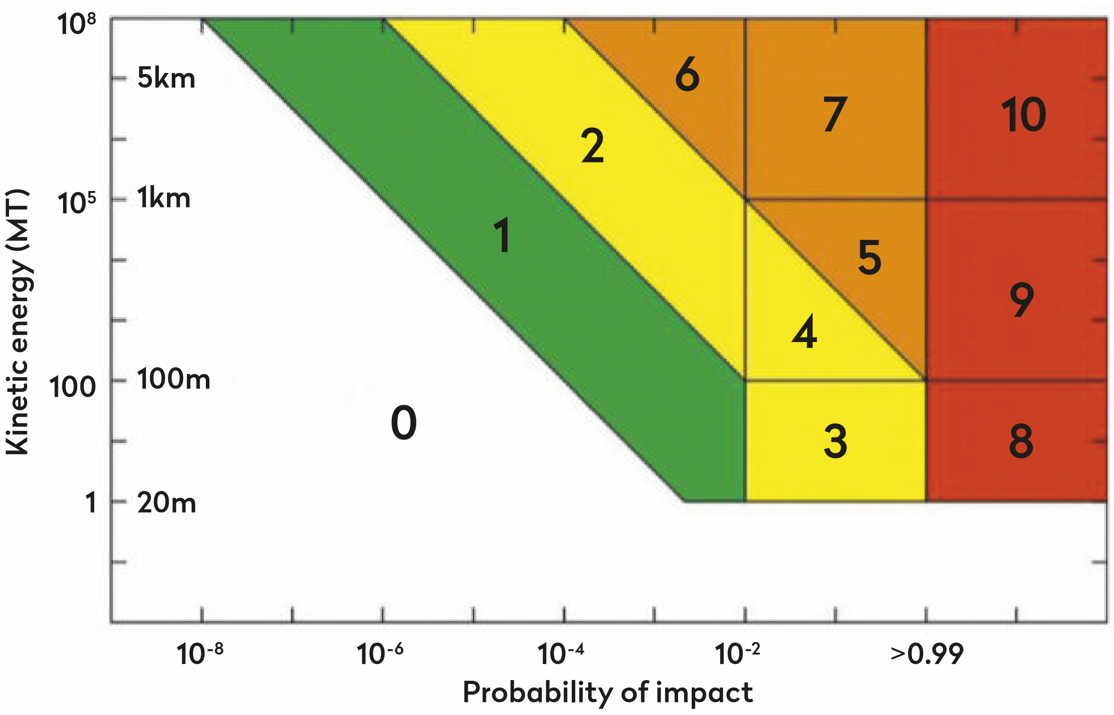
Any asteroids that are considered to have a reasonable risk of significant impact have their orbits forecast for the next hundred years. If there is the smallest possibility that the asteroid's path can cross Earth's, it is observed and studied as much as possible. There are two scales to rate the risk of a possible impact. The Palermo Scale compares the likelihood of potential impact by the detected object with the average risk posed by objects of the same size or larger over the years until the date of the potential impact. The Torino Scale is simpler: it uses numbers from 0 to 10 to show the level of hazard, where 10 corresponds to a "collision that may threaten the future of civilization". At the moment none of the asteroids that have been discovered exceed zero.

Sandra Kropa is a science journalist and writer. Based in Latvia, she appears on television and radio

NASA/GODDARD/UNIVERSITY OF ARIZONA, NASA/JPL-CALTECH



We currently know of about 20,000 NEOs (near-Earth objects), shown here in this NASA representation. Main-belt asteroids are orange and NEOs are light blue



▲ **The Torino Scale rates the level of impact threat from an asteroid, based on both the probability and severity of impact from 0 to 10**

However, the gravity of other planetary bodies within the Solar System, especially planets like Earth, Jupiter and Mars, can deflect space rocks from their initial orbit, potentially sending them on a future collision course they weren't initially on. The gravitational effects of all the planets and even some of the biggest asteroids are considered in modelling the trajectory of an asteroid. Apophis's close pass with Earth in 2036 might change its orbit, creating an impact risk in 2068, meaning astronomers will have to re-determine the space rock's orbit after that pass.

But it's not only gravity that increases such a risk. For asteroids, especially those smaller than 10km in diameter, a contributor to the uncertainty is the Yarkovsky effect – a force acting on a rotating body, caused by the change of temperature of an object warmed by radiation. This also applies to the asteroid Apophis.

"For a better knowledge of the trajectory of Apophis in the later part of this century and its sequence of encounters with the Earth, we need to wait for tracking data taken through the 2029 encounter. For 2036, we cannot yet say whether Apophis will make a close approach, but even if it does, we already know the orbit of the asteroid well enough to say that it cannot impact the Earth that year. The impacting trajectories we identify for a year such as 2068 properly account for the gravitational influences of encounters in prior years," says Farnocchia.

From the almost 20,000 near-Earth asteroids currently known, more than 800 are currently on the risk list. This list is constantly changing because newly discovered objects are being entered onto it and, because of continued updates of observation data, other objects are being removed.

At the moment there are no asteroids considered a direct threat, but knowing that there are hundreds of thousands that remain unseen, uncharted and subject to change, we definitely cannot forget about them.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Heights of summer: noctilucent clouds are lit when the Sun is below the horizon

Getting ready for NLCs

How to catch high-altitude noctilucent clouds

Noctilucent clouds (NLCs) are a summer phenomenon, typically seen from latitude zones 50–70° in both the Northern and Southern Hemispheres. The northern displays appear from late May and may be visible at unpredictable times throughout June, July and early August. There are no guarantees a display will happen at all over this period, but it would be unusual to get nothing. Some years produce weak NLCs, while others are strong. A run of weak years may produce indifference in NLC hunting but a strong resurgence, such as last year, can re-energise a desire to see them.

NLCs are high-altitude clouds formed in the mesosphere, a thin layer located around 82km up, approximately seven times higher than 'normal' clouds. They are still bathed in the Sun's light even though, from the ground, the Sun is below the horizon. What you see is a reflection of sunlight from the NLC layer.

They can be mesmerising, often appearing with an intricate structure glowing with an electric blue colour. The fact that they appear to shine against the dark of night, or at least a deep blue twilight, gives them their name 'noctilucent' meaning 'night shining'.

Photographing NLCs is straightforward and can be done with a wide variety of equipment, including camera phones. The skill is assessing how bright the scene is and how to set your camera accordingly. If the scene and NLCs appear relatively dark, a higher ISO may work well, but it may produce a noisy image with unwanted artefacts. Mounting the camera on a tripod or a fixed platform will allow you to keep the ISO low and compensate by taking longer exposures.

NLCs, like regular clouds, do appear to move, normally quite slowly but they can pick up the pace. Too long an exposure could lead to NLC motion blur.

Then there's the background sky. If visible, NLCs normally make an appearance when the background sky has dimmed sufficiently to allow their delicate glow to shine through. This happens between 90–120 minutes after sunset and a similar time before sunrise. The evening period has the Sun located below the northwest horizon, so this is where the NLCs can be seen if present. Similarly, the morning period has the Sun located below the northeast horizon and this is where the morning display is likely to be seen.

It's not a hard and fast rule though, and exceptions occur. A bright display may appear first in the northwest, tracking through north as the Sun creeps its way below the northern horizon, to finish in the northeast as described. Sometimes NLCs are extensive enough to appear outside their normal display areas.

As an NLC photographer you need to have your equipment charged and at the ready. Locate an area which is both dark at night and presents a low horizon in the direction you need; northwest in the evening and northeast in the morning. NLCs can have a low altitude and are lost behind buildings.

A wide-angle camera can produce some amazing images, but magnified telephoto views or even telescope setups can give interesting results, where you can home in on one area of NLC activity.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: Digital camera, support device – ideally a tripod, remote shutter control

Send your images to: gallery@skyatnightmagazine.com

STEP 1

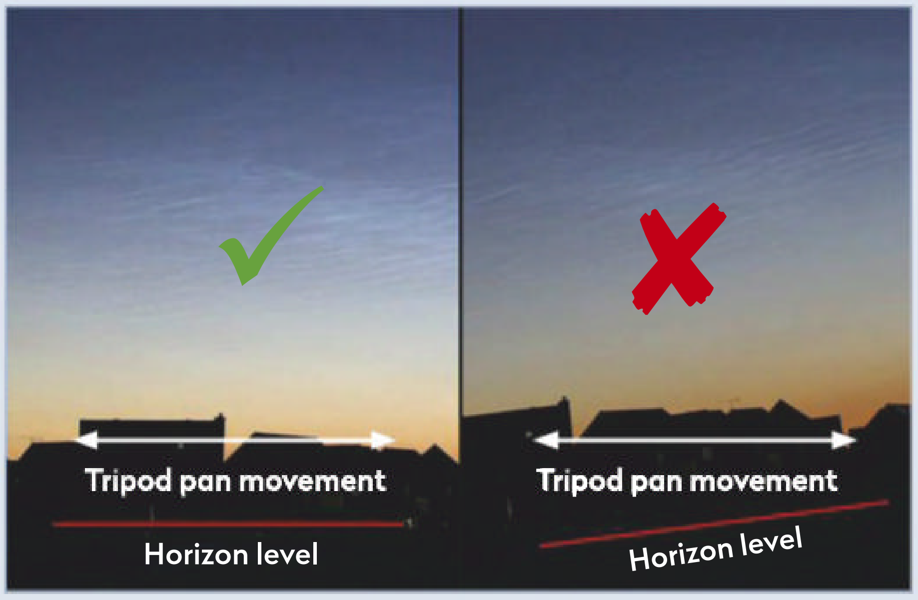
NLCs can appear bright enough for many modern devices to pick up, including smartphones like the image above. Pre-focus a mid or wide-angle lens at infinity, set the camera ISO between low and mid level and use a low f/number. Mount the camera on a stable platform and use a shutter release cable for a 1 second exposure.

STEP 2

Examine the result. If it looks too dark increase the exposure time in increments of 1 sec up to, say, 20 secs maximum. If you hit this barrier and the images are still too dark, increase the ISO. Due to changes in sky brightness and NLC appearance, monitor images over a session and adjust exposure and/or ISO settings.

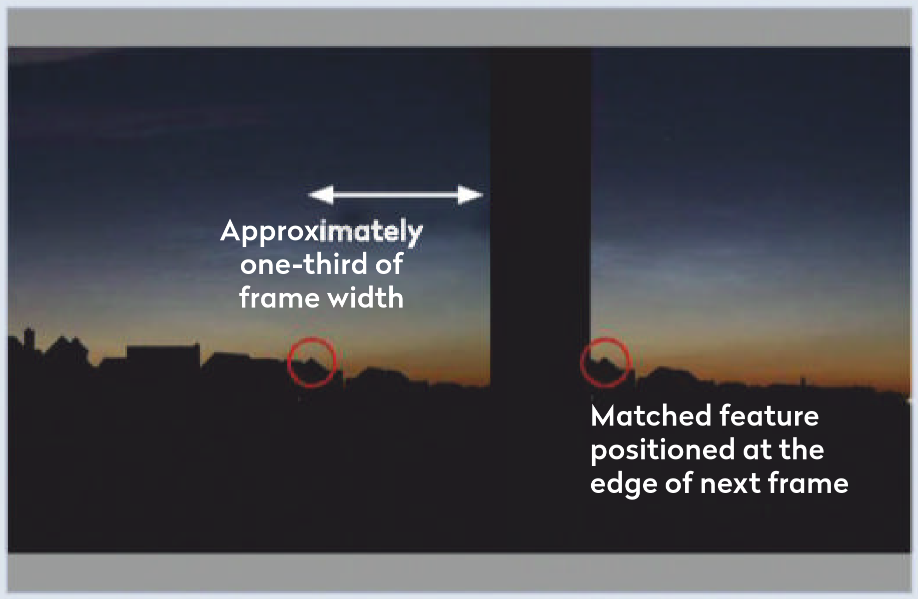
STEP 3

NLC displays often cover a wide azimuthal range and it's not uncommon for mid-angle lenses not to be able to cover everything in one shot. If you have a panoramic imaging app on your smartphone this may be one option, or stitching images from a conventional camera may produce a better result.



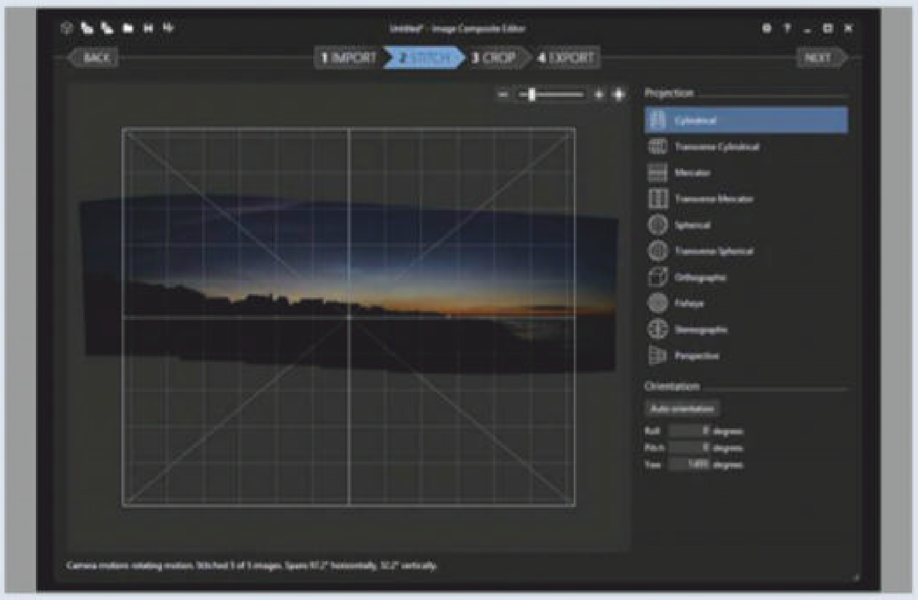
STEP 4

For a DSLR panorama, mount the camera on a tripod and level it so that panning horizontally keeps the bottom of the image frame parallel to the horizon. Make a test exposure at both ends of the display and examine the results. The brightest end should not burn out to white and the darkest needs to reveal some detail.



STEP 5

Pick an end to start from and frame the display so the start of it is in from the frame edge by say one-quarter the frame width. Make an exposure. Note a feature on the horizon about one-third to one-quarter in from the image edge in the direction you'll be panning. Pan across so that feature is on the opposite edge.



STEP 6

Work your way along the display so that you have covered everything. When building the panorama, automated software such as Microsoft's free Image Composition Editor (bit.ly/2G1tjyD) will help. Drag each component into the program's main window and the application will do the rest.

Applying the finishing touches with PixInsight

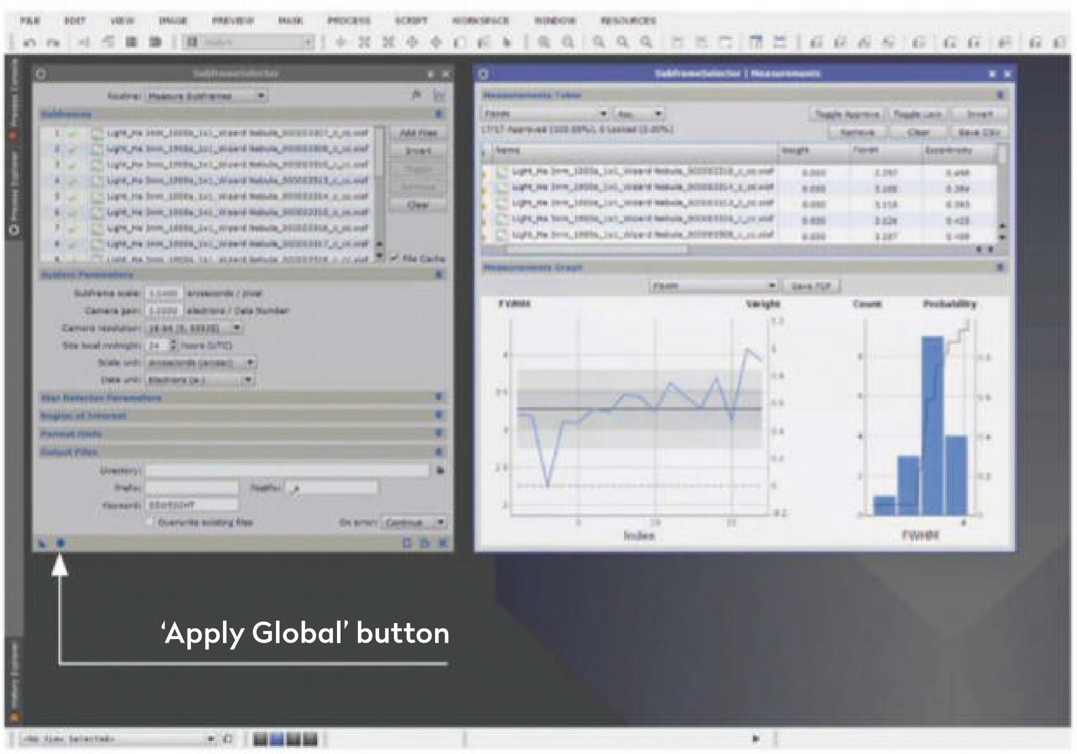
Using aligning and stacking techniques on calibrated images will create an overall smoother picture

Recently, in the April issue, we showed how to prepare images by calibrating them with Bias, Dark and Flat frames to remove unwanted artefacts. With your image data calibrated you can move to the next stage of image processing, to align and stack multiple images into a single image using PixInsight.

Stacking your images increases the signal to noise ratio, releasing otherwise hidden detail and producing an overall smoother image with an optimised dynamic range. If you have dithered your images – by creating the illusion of colour depth with a limited colour palette – at capture time, then choosing the correct stacking algorithm within PixInsight will also remove any remaining hot pixels. Hot pixels are the unwanted individual pixels that appear brighter than they should. The more images that you include in the stack, the better the result, although after 30 or so images there are limited benefits. PixInsight calls this process 'integration' but before your images can be integrated they must first be aligned with one another in a process known as registration. The stars themselves are an excellent source of registration data. If you align the stars in each image with a reference image, you'll find that the deep-sky object that you are imaging will also be perfectly registered between each image.

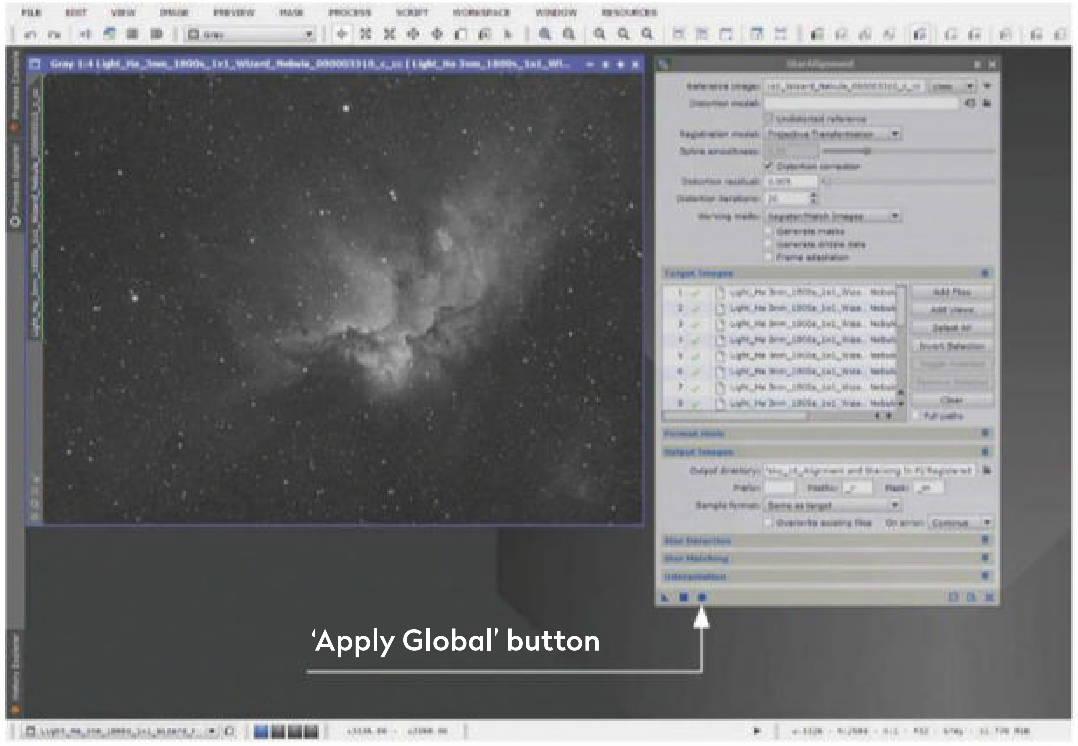
You should use your 'best' subframe as the reference image for both the registration and integration processes. Although PixInsight has a powerful process for analysing your images, for the purposes of this article we'll use its most basic function. Select Process › ImageInspection › SubframeSelector. Click on the 'Reset' button at the bottom right-hand corner of the screen to default all the settings and then click the 'Add Files' button. Choose all the subframes that you previously calibrated and cosmetically corrected to populate the Subframes list. Next, enter the values belonging to your imaging system in the System

▲ **A single calibrated subframe awaits registration and stacking with other images**

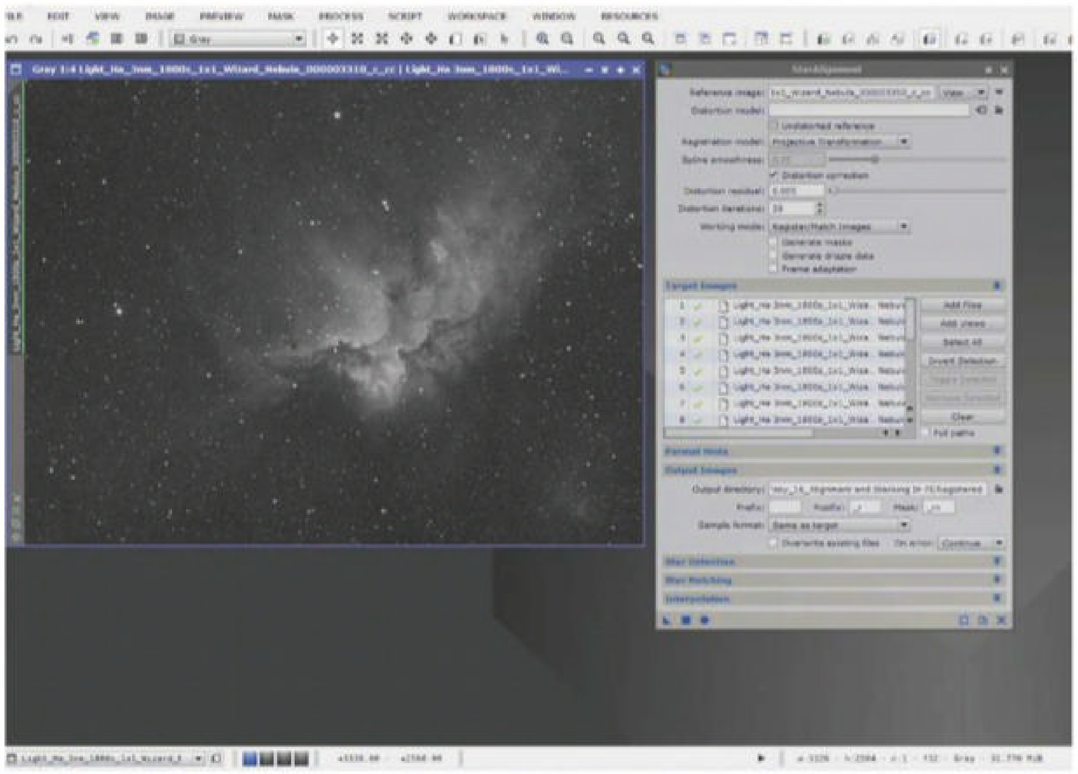


▲ **The SubframeSelector process showing the distribution of FWHM values**

ALL PICTURES: STEVE RICHARDS



▲ **The StarAlignment process using a view image as the reference image**



▲ **The ImageIntegration process with the integrated image ready for saving**

Parameters box and click 'Apply Global' to analyse the images. Note the subframe that has the lowest FWHM value and use it as your reference image.

Register the images

Having chosen a suitable reference image, close the SubframeSelector and select the StarAlignment process – Process › ImageRegistration › StarAlignment. Click on the 'Reset' button at the bottom right of the screen to default all the settings. Either load your reference image and select it from the 'View' drop-down menu or change from 'View' to 'File' and select the reference image from its subdirectory. Place a tick in the 'Distortion Correction' box by clicking on it and leave the other settings as defaults. Again, click on the 'Add Files' button and choose all the subframes that you previously calibrated and cosmetically corrected to populate the Target Images list. In the Output Images section, choose an output directory for the registered images to be saved in, leave all other settings at their defaults then click on the 'Apply Global' button to register the images and save them automatically. You can now close the ImageRegistration process.

Next is the stacking process which is carried out on the aligned images. Start by loading the ImageIntegration process: Process › ImageIntegration › ImageIntegration. Click on the 'Reset' button at the bottom right-hand corner of the screen to default all the settings. Populate the Input Images section by clicking on the 'Add Files' button and select all the registered images produced by the StarAlign process. Highlight the same image that you selected as the best during the ImageRegistration process to use as the reference image from the list and select it by clicking on the 'Set Reference' button. It will move to the top of the list and be highlighted in orange.

In the ImageIntegration section, leave the settings as defaults. Open the Pixel Rejection (1) section by clicking on the double down arrows to its right. Choose the correct Rejection algorithm to remove unwanted outlier artefacts and get the best match for your data. Resting a cursor over the drop-down menu box opens a pop-up box explaining various methods. Always try to capture at least 10 good images and use the Winsorized Sigma Clipping algorithm when possible. It is best practice to use dithering during the image capture process as this helps the integration algorithm to identify outlier pixels and remove them. Leave all the other settings at their defaults then click on the 'Apply Global' button to integrate the images into a single one. Finally, save the image with a suitable name in a subdirectory by selecting File › Save As, so you have a safe copy ready for further processing.

Steve Richards is an astro imager and author of *Making Every Photon Count: A Beginner's Guide to Deep Sky Astrophotography*

The final Wizard Nebula image, produced by the alignment and stacking processes

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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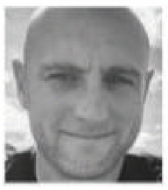
PHOTO OF THE MONTH

△ The Heart and Soul Nebulae

Keith Bramley, Lancashire, 14–22 February 2019

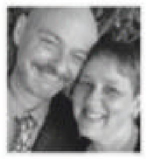


Keith says: "I have always wanted to image this area of the sky and my current wide-field setup has a perfect field of view for such a large target. I began collecting the data on Valentine's Day, so the Heart Nebula seemed appropriate. It did take several nights, however: over a week to gather all the image data due to the challenging conditions and intermittent cloud. The images at the end of the week were impacted by the full Moon so I found them becoming slightly washed out, even with narrowband filters.

Equipment: Atik 383L+ mono camera, Samyang 135mm f/2 telephoto lens, Sky-Watcher EQ6 Pro mount.
Exposure: 36x300" each Ha, SII, OIII
Software: Artemis Capture, PHD2, DeepSkyStacker, Photoshop

Keith's top tips: "For deep-sky imaging the most important part of your setup is your mount. Spend time tuning out any slop in the tracking and reduce any differential flexure between the main scope and the guidescope. This will help keep the stars nice and round over longer guided exposures. However, a slight drift over a longer period can be beneficial as it allows you to use advanced stacking routines such as Kappa-Sigma clipping (removing unwanted pixels) without having to 'dither'. This removes the need for dark frames and allows you to stack images with satellite and aircraft trails."

◁ Six-day old waxing crescent



Sarah and Simon Fisher, Worcestershire, 12 March 2019

Sarah says: "Simon and I were thrilled to get this grab and go shot, as the weather was somewhat changeable that night. We were cloud-dodging and it was very blustery."

Equipment: Canon EOS 600D DSLR camera, 127mm Maksutov. **Exposure:** ISO 800, 1/125" **Software:** MacBook Pro

▽ Bode's Galaxy

James Harrison, Oxfordshire, 18 & 26 February 2019

James says: "Issues with guiding caused by dew, focuser slip and clouds cost me about two thirds of my exposures, but the remainder were usable. After a couple of attempts, I produced the first galaxy image I'm really proud of, though there's always room for improvement."

Equipment: ZWO ASI183MM-PRO mono camera, Sky-Watcher Explorer 200PDS Newtonian, Sky-Watcher EQ6-R Pro mount. **Exposures:** L 5x300", 8x60"; R 10x120"; G 13x120"; B 9x120" **Software:** INDI, Ekos, KStars, PixInsight

△ Northern Lights

David von Janowski, north of Øksfjord, Norway, 9 February 2019

David says: "I am very pleased with this photo as it was taken without a tripod on a moving ship at sea and is a lasting record of my achievement seeing the Northern Lights. The shimmering glows viewed on the Norway Cruise were a surprise as the colour was more white seen by the naked eye than expected."

Equipment: Pentax K20D camera, Sigma DC 18-200 zoom lens. **Exposure:** ISO 800, 16" **Software:** PhotoScape

◁ The Statue of Liberty Nebula

Rafael Compassi, Presidente Lucena, Brazil, 5 March 2019

Rafael says: "This target is a perfect fit in the CCD field and responds extremely well to narrowband imaging. Using narrowband I managed to capture the Ha (Hydrogen-alpha) loops on top of the nebula and the faint background clouds."

Equipment: ZWO ASI 1600MM-C mono camera, William Optics FLT Fluoro Star 132mm f/7 triplet apo refractor. **Exposure:** 49x300" Ha; 35x300" OIII. **Software:** AstroPhotography Tool, PixInsight

△ Milky Way

Kevin Stewart, Dunstanburgh Castle, Northumberland, 8 March 2019

Kevin says: "This location has little light pollution, which enabled a great shot of this iconic landmark on the north east coast. I am very pleased with the end result."

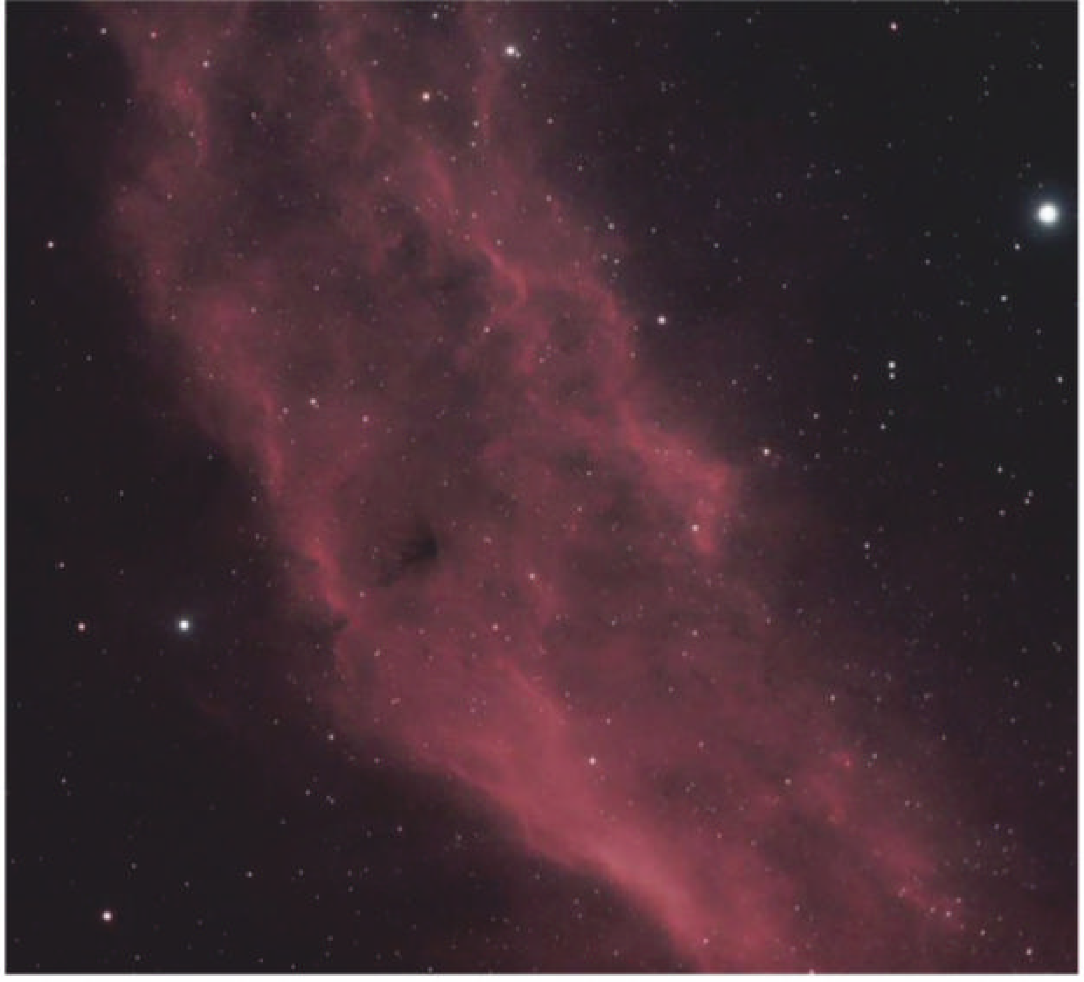
Equipment: Canon EOS 6D DSLR camera, Samyang 14mm f/2.4 lens, Manfrotto tripod. **Exposure:** ISO 12800, 3x20" **Software:** Microsoft ICE

◁ M106

John Tonks, Pembrokeshire, 7 March 2019

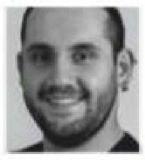
John says: "This is one of my favourite targets. Other visible galaxies in the image are NGC 4248 and UGC 7356"

Equipment: ZWO ASI1600MM mono camera, 180mm Maksutov-Cassegrain, Sky-Watcher EQ6-R Pro mount. **Exposure:** L 40x300"; RGB 40x120" **Software:** AstroPhotographyTool, Astro Pixel Processor, StarTools



◁ The California Nebula

Ruzeen Farsad, Kettering, 11-27 February 2019

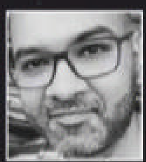


Ruzeen says: "While booming and busy nebulae are nice, there's something appealing about how minimal this one is. I was keen on learning about HaRGB (Hydrogen-alpha, Red, Green and Blue) composites, so I imaged this target to practise and learn how to do just that. It took a few processing passes but I'm happy with the end result."

Equipment: Canon EOS 450D DSLR camera, Sky-Watcher Evostar 80ED Pro refractor, Sky-Watcher HEQ5 Pro SynScan mount **Exposure:** ISO 800, 12.8h Ha; 9.5h broadband. **Software:** PHD2, AstroPhotography Tool

The Jellyfish Nebula

Ahmed Rizwan Khan, London, 1-3 March 2019



Ahmed says: "In 2010 I first saw an image of this nebula published and I could not believe that an amateur astronomer using a humble telescope living just a few miles from my home could capture it with such clarity. This kick-started my journey into astrophotography."

Equipment: ZWO ASI 1600MM-C mono camera, Sky-Watcher Esprit 100ED Pro triplet refractor, Sky-Watcher NEQ6 Pro SynScan mount. **Exposure:** 80x300" each Ha, SII, OIII **Software:** Sequence Generator Pro, PixInsight

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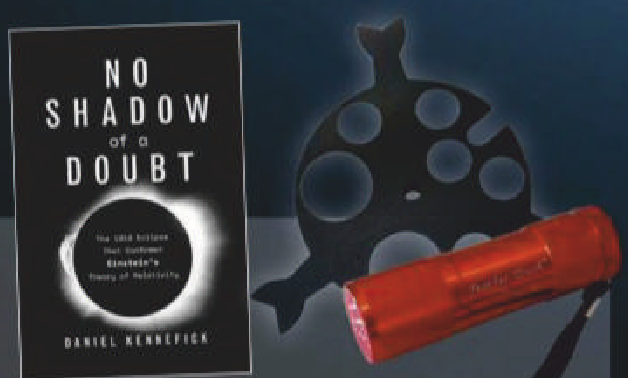
Discover how well the Vixen FL55SS flourite apo refractor measures up for astrophotography



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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Vixen
FL55SS fluorite apo refractor

A portable scope designed for astrophotography that also works well visually

WORDS: TIM JARDINE

VITAL STATS

- **Price** £1,149 (Reducer HD Kit £799)
- **Optics** Apochromatic fluorite objective lens
- **Aperture** 55mm
- **Focal Length** 300mm, f/5.5 native, or f/4.3 with reducer and flattener
- **Focuser** Dual speed rack and pinion
- **Weight** 1.49kg OTA, 1.95kg with Reducer HD Kit
- **Supplier** Opticron
- **Tel** 01582 726522
- **www.** vixenoptics.co.uk

Vixen has a fine pedigree of telescopes, and new models from the Japanese company always attract their fair share of interest. This is the case with the FL55SS, a compact and lightweight refractor that offers premium features in a portable package.

The FL55SS is a dual-purpose telescope suitable for visual astronomy, or with the addition of a dedicated lens kit, for fast, wide-field astrophotography. The unit is supplied as an OTA, or Optical Tube Assembly only, so to test it visually we used our own 1.25-inch diagonal. An extension tube for the visual back is supplied, which allows the scope to be used in a straight through configuration if desired. Without a diagonal, however, we found this was an uncomfortable way of viewing objects that were high overhead. If you are considering the FL55SS as a visual instrument, then a high-quality, maximum light transmission diagonal would be a worthwhile investment, to ensure optimal results from the front end's petite 55mm objective lens.

Bright ideas

We began our visual session with basic checks for astigmatism, lens misalignment and mechanical issues. As expected with Vixen equipment we found no problems. The telescope has a native focal length of 300mm, so our 25mm Plössl eyepiece, giving just 12x magnification, provided a wide overview – useful for orientation as there is no finderscope included with the FL55SS. The view proved to be too bright as poor sky transparency amplified the effect of background light pollution, but it did highlight the potential for the telescope in dark sky areas. Our 10mm eyepiece with its 72° field of view giving 30x magnification, was more rewarding: the star field contrasted nicely against the background. Bright stars such as Regulus and Arcturus demonstrated their distinctive blue and red hues respectively, and there were no unwanted colour aberrations visible around them. Moving the brighter stars towards the ▸

Fancy flourite

Many telescopes contain objective lenses made of glass. In contrast to this, the FL55SS uses fluorite, which is a crystal. Fluorite is expensive to produce, being fragile and difficult to work on, but fluorite has optical properties that make it very desirable as light can pass through it with minimal dispersion, unlike glass. In practice this means that the overall view is sharper, as all the colours of light entering the telescope are focused to a single point, rather than being dispersed into a fuzzier appearance. Fluorite lenses reduce chromatic aberration, an effect usually seen as unwanted coloured rings around brighter objects. Using parfocal colour filters and a CCD camera on the OTA alone, we checked the focus point of red, blue, and green light in comparison to each other – and as a whole through a luminance filter – to see just how good the fluorite lens is. The results were encouraging; red and green light focused together, with just a tiny deviation towards blue. This result is typical of high-end apochromatic telescopes.

SCALE

Built-in dew shield and tube internals

A generous built-in dew shield helps to prevent problems with dew and restricts stray light from entering the scope and interfering with the view. Internal surfaces of the dew shield and scope are treated with a flat black coating, helping to eliminate reflections that reduce contrast at the eyepiece or camera.

Lightweight and compact

The fit and finish of the FL55SS is high quality and the Vixen-style dovetail bar, although removable if required, forms an integral part of the telescope assembly. The tube itself measures just 282mm and weighs 1.5kg. Combined with the Reducer HD Kit the total weight is below 2kg.

Dual-speed rack and pinion focuser

Smooth and precise focusing is a prerequisite for fast astrographs with a shallow depth of focus. The no-nonsense, dual-speed, rack and pinion focuser offers just that, with a solid, sturdy-feeling adjustment mechanism, no slop in the drawtube and no change in focus when locking it in place.

FIRST LIGHT

▸ edge of the eyepiece started to reveal the effects of coma, which was quite pronounced at the perimeter. In the 10mm eyepiece the Great Hercules Cluster, M13, was a bright, but fairly indistinct object, but swapping to a 4.5mm eyepiece revealed more individual stars. At 66x the view was darkened, the brighter stars were tight and round with text-book airy discs, and we felt that we had probably reached the maximum useful magnification.

Kitted out

The primary purpose of the FL55SS, though, is a portable high-quality astrograph, when it is married to the Vixen SD Reducer HD Kit and a suitable camera. The kit is specially designed to complement the telescope; it includes a flattening lens to remove coma and a reducing lens to widen the field and lower the focal ratio from f/5.5 to f/4.3. There is also an extension tube that allows the flattener to be used separately from the reducer if desired.

Connecting a camera to the FL55SS requires a Vixen 60mm-adaptor. We borrowed one for our full-frame Canon 6D DSLR and then pointed the telescope towards Orion. The field of view on offer was tantalising, easily framing the three stars of Orion's Belt, and down beyond the Sword. Our imaging opportunities were limited, but the fast optics allowed even a handful of 30-second exposures at ISO 1600 to begin revealing objects like the Flame Nebula and glimpses of the Horsehead Nebula. Markarian's Chain of galaxies seemed another natural target for this equipment, and even a cropped photo easily contained the triangle formed by M58, M91 and M84, with dozens of faint galaxies alongside. More compact targets, like the Moon, or the Great Hercules Cluster are captured in the context of the sky around them, but the rich star field around the Great Hercules Cluster, M13, demonstrated that the flattening lens does its job well. Stars in the corners of the full-frame image started showing slight curvature, but the majority of the image had good, round stars.

Lightweight, compact, easy to use and effective both visually and photographically, the Vixen FL55SS proves its worth as a telescope and an astrograph.

VERDICT

Build and design	★★★★★
Ease of use	★★★★☆
Features	★★★☆☆
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

Reducer HD

Taking the focal length to 237mm when used with the flattener, this 0.76x reducer comprises of three lenses and lowers the focal ratio to f/4.3. It's perfect for astrophotography, especially on portable mounts where less accurate tracking requires shorter exposures. An imaging circle of 44mm is quoted.

Flattener HD

This two-element lens removes the inherent coma of the main objective lens and acts as a slight 1.04x Barlow. The resulting imaging circle has a 44mm diameter. The flattener attaches to the reducing lens, or to an included extension tube, and fits inside the focuser drawtube.

KIT TO ADD

1. 7x50 finderscope

2. Holder for 7x50 finderscope

3. Finderscope holder shoe

◂ A slightly cropped image of Orion's Belt and Nebula, as viewed through the Vixen FL55SS scope and captured with a Canon 6D DSLR, using exposures of 9x30 seconds at ISO 1600

▴ The Vixen's view of M13, captured on a Canon 6D using 50x45 second exposures at ISO 1600. The flattening lens works well on the star field

Our experts review the latest kit

6 OF THE BEST

2-inch dielectric diagonals £99–£200

Sky-Watcher Deluxe Dielectric Coated 90° Star Diagonal

Price £109 • **Surface reflection** 99% • **Weight** 470gm • **Extras** 2 dust caps, 1.25-inch adaptor, barrel filter threaded for 2-inch filters • **Supplier** Optical Vision Ltd • **Tel** 01359 244200 • **www.**opticalvision.co.uk

The Sky-Watcher Deluxe is a straightforward diagonal – designed to put eyepieces at a comfortable angle to look through – that uses dielectric coating to give the maximum light transmission of 99 per cent. In all our tests it gave brighter views compared with our basic test 2-inch diagonal. The internal baffling was good, with little in the way of internal reflections when we viewed the Moon. The stars remained crisp, but, when compared with some of the others on test, we had an impression of slightly less contrast in deep sky objects such as the Great Globular Cluster, M13, and the galaxy pair M81 and 82.

As we slotted our 2-inch eyepiece in and out, we noticed how the Sky-Watcher diagonal showed good quality-machining, combining a sleek design with smooth operation. The diagonal can take 2-inch filters in the threaded barrel, which is useful if you intend on using a light pollution filter. Packaged in a basic black box, the diagonal does its job well.

VERDICT

A good overall performer with no frills
FOR Simple and easy to use
AGAINST Slightly less colour contrast in stars

OVERALL SCORE ★★★★☆

Altair 2-inch Positive Lock 90° Prism Diagonal

Price £125 • **Surface reflection** 99% • **Weight** 646g • **Extras** 2 dust caps, 1.25-inch adaptor, positive-Lock, barrel filter threaded for 2-inch filters • **Supplier** Altair Astro Ltd • **Tel** 01263 731505 • **www.**altairastro.com

The Altair Positive Lock was the white sheep of the pack, as its body stood out among the other black-coated diagonals. It will certainly be easy to spot in the dark and you won't bump into it with your head. It's the heaviest diagonal, at 646g, and it felt like a good sturdy piece of kit.

In our practical tests the Altair diagonal gave the best colour rendition of Arcturus, the brightest star in the constellation of Boötes. The internal baffle's matte coating did its job: we had good contrast in our views of the deep sky and the Moon showed no internal reflections. A real plus, however, is the Positive Lock knurled ring which, when turned, locks the eyepiece firmly in position. It was so efficient that we felt the supplied thumbscrew was almost unnecessary. It's one of those simple ideas that deserves to catch on and be incorporated as a standard feature on all star diagonals. A nice touch, the ring held our large, heavy eyepiece perfectly.

VERDICT

Excellent performer overall despite the weight
FOR Positive Lock held eyepieces securely
AGAINST Heaviest diagonal of the six

OVERALL SCORE ★★★★★

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Explore Scientific Diagonal Mirror 2-inch

Price £142 • **Surface reflection** 99% • **Weight** 466g • **Extras** 2 dust caps, 1.25-inch adaptor, barrel filter threaded for 2-inch filters • **Supplier** Telescope House • **Tel** 01342 837098 • **www.**telescopehouse.com

Like all the test diagonals, the Explore Scientific boasts a reflectivity of 99 per cent due to the dielectric, coated mirror. It weighs in as the lightest model, at 466g, yet its sturdy and could easily handle our 21mm Ethos eyepiece, which itself weighs just over 1kg. Unlike the other review models, it uses two thumbscrews to apply pressure to the brass compression rings that held the 2-inch fit eyepiece firmly in place. Just like the rest, it uses a single thumbscrew to hold 1.25-inch fit eyepieces via a compression ring on the adaptor. The contrast on our various test subjects was good and showed how well the matte coating inside cuts down on internal reflections. The only surprise was that the mirror juts out a little into the end barrel clipping the view, yet visually we didn't notice any detrimental effects. The Explore Scientific 2-inch diagonal is supplied in a very smart well-padded box that sets it apart from the rest.

VERDICT

Well packaged and lightest of the group yet still quite capable
FOR Two thumbscrews to hold 2-inch eyepiece in place
AGAINST Bottom edge of mirror visible from barrel end

OVERALL SCORE ★★★★☆

Revelation Diagonal Dielectric 99% Quartz 2-inch

Price £139 • **Surface reflection** 99% • **Weight** 530g • **Extras** 2 dust caps, recessed 1.25-inch adaptor, barrel filter threaded for 2-inch filters • **Supplier** Telescope House • **Tel** 01342 837098 • **www.**telescopehouse.com

The Revelation Diagonal Dielectric Quartz is solidly built with a practical design and it's the only model featured with a silver end barrel – helping it to stand out. It also features an unusual recessed 1.25-inch adaptor that allows eyepieces to have a lower profile, instead of jutting out like the rest of the diagonals on test. The internal baffle coating surprised us as it appeared to be far shinier than the others in the review, suggesting the possibility of internal reflections when viewing the Moon. However, we saw little detrimental effect when we tested it with our lunar target and bright stars. The dielectric coating had the strongest green hue of the diagonals we were testing, yet the contrast when viewing deep sky targets – such as a wide-field view of the Orion's Belt and Sword region – was very enjoyable. Despite being midway in weight and not the lightest on test, the Revelation performed well visually. The only concern was that the 1.25-inch adaptor felt a little tight when it was taken out and put back into the telescope focuser. ►

VERDICT

Interesting design and good performance
FOR Recessed 1.25-inch adaptor for eyepieces
AGAINST Adaptor a little awkward on insertion and removal

OVERALL SCORE ★★★★☆

6 OF THE BEST

Omegon Star Diagonal with 99% reflection, 2-inch

Price £99 • **Surface reflection** 99% • **Weight** 470g • **Extras** 1.25-inch adaptor, 2 dust caps, barrel filter threaded for 2-inch filters • **Supplier** Omegon • **Tel** 020 386 88042 • **www.**omegon.eu

The Omegon bears a strong resemblance to the Sky-Watcher Deluxe model and we found little to distinguish between them performance-wise. Its overall look is stylish, with a sleek curved neck, and a nicely fitting and smooth-to-use 1.25-inch adaptor that uses brass compression rings to hold the eyepiece in place. We found this did the job nicely, with no sign of slippage when our review scope was aimed at targets high in the sky. The internal baffling was matte black and when we looked at the Moon we saw little in the way of internal reflections, showing the internal dark coating was doing its job. Like the Sky-Watcher, we did suspect that the contrast on deep sky targets was a little less compared with the others on test, but we felt the effect was minimal and did not really detract from the views. The dielectric-coated mirror was well positioned and did not protrude into the end barrel, allowing a clear view.

VERDICT

A simple design that does the job without any fuss
FOR Good internal blackout
AGAINST Slightly less contrast in deep-sky targets

OVERALL SCORE ★★★★☆

William Optics 2-inch Dura Bright Dielectric Carbon Fibre

Price £135 • **Surface reflection** 99% • **Weight** 540g • **Extras** 2 dust caps, 1.25-inch adaptor, barrel filter threaded for 2-inch filters, temperature gauge • **Supplier** Widescreen Centre • **Tel** 020 7935 2580 • **www.**widescreen-centre.co.uk

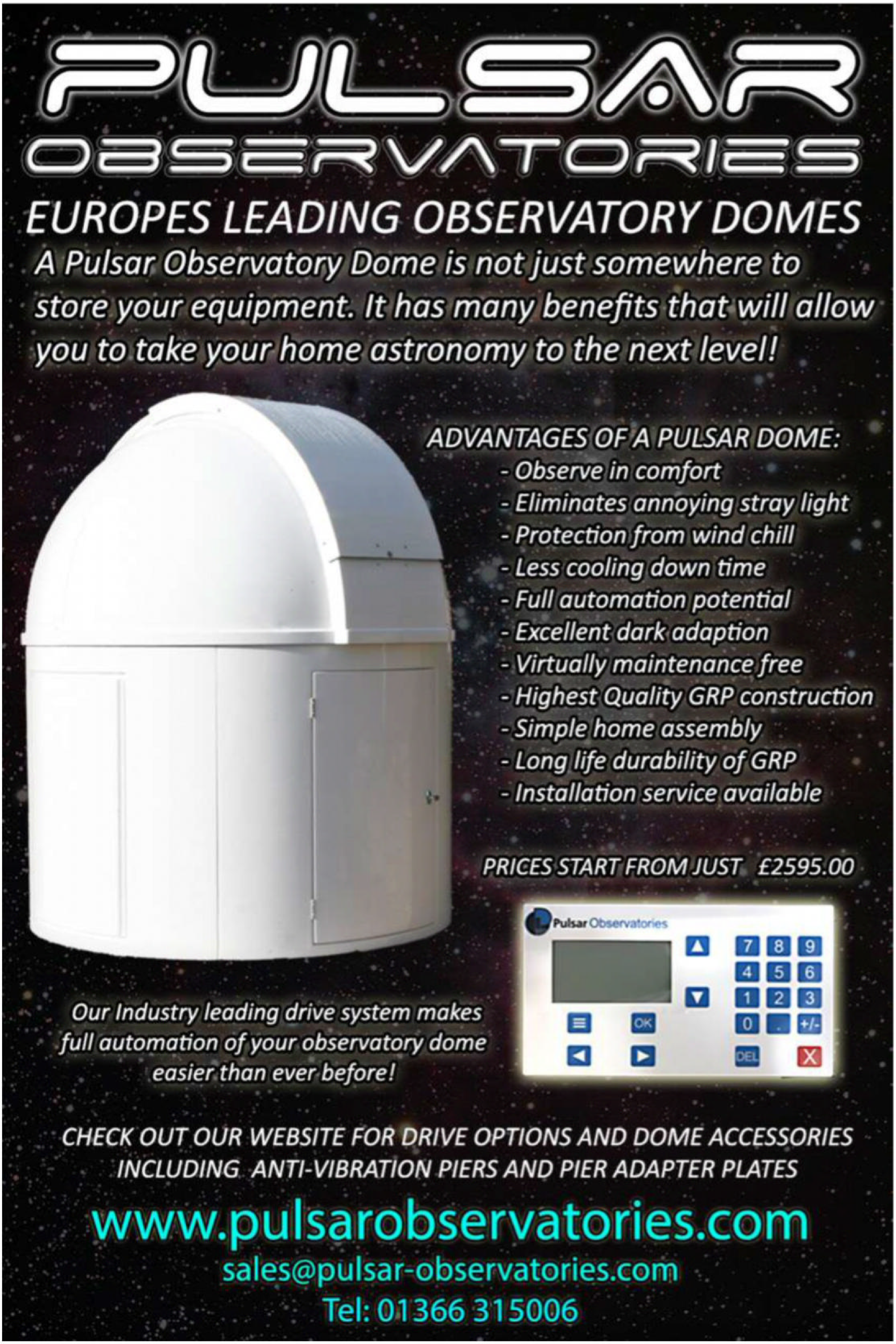
William Optics has a reputation for manufacturing high quality telescopes and accessories and its Dura Bright 2-inch Dielectric Carbon Fibre diagonal lives up to this reputation. It exudes quality, looking a bit like a cross between the Explore Scientific and Sky-Watcher diagonals, and it's supplied in a well-padded plain black box. The end barrel is threaded internally for 2-inch filters while the internal baffle coatings are matte black with little, if any, sign of reflections or loss of contrast when used on the Moon, bright stars or deep sky. We found that eyepieces were easy to slot in and take out, regardless of either 2- or 1.25-inch fit, and it held them rigidly, especially considering the weight of our 21m Ethos eyepiece used in the review. A useful addition is the thermometer on one side which is handy when using the diagonal for imaging, as you can control the camera temperature more accurately by referring to it.

VERDICT

Stylish, well-made and a pleasure to use
FOR Good colour contrast for the stars and bright views
AGAINST Second heaviest of the review

OVERALL SCORE ★★★★★

ALL PICTURES: WWW.THESECRETSTUDIO.NET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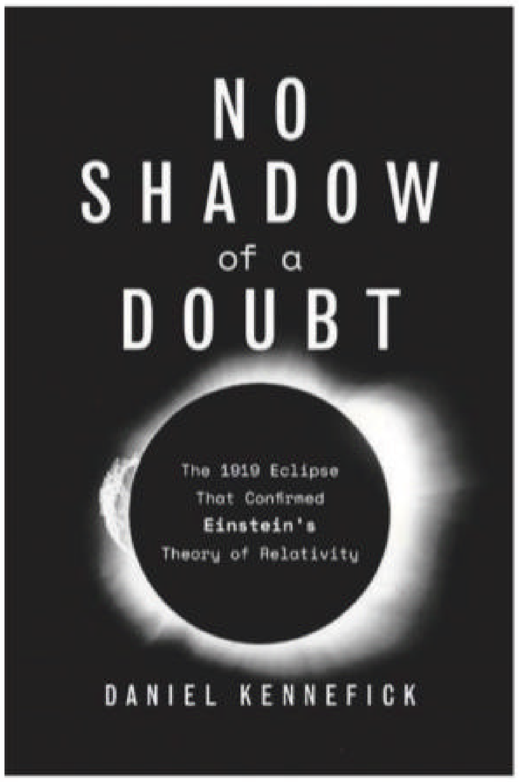
New astronomy and space titles reviewed

BOOKS



No Shadow of a Doubt

Daniel Kennefick
Princeton University Press
£24 ● HB

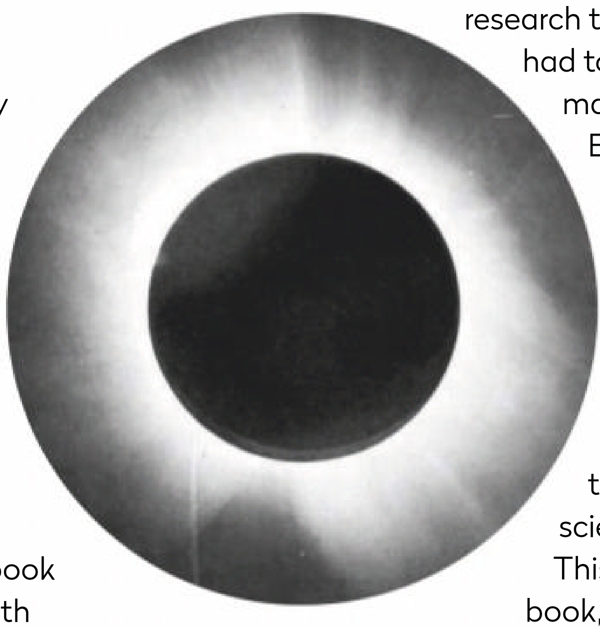
At 2.13 GMT on 29 May 1919, Arthur Eddington and Frank Dyson were on the island of Principe, west of Africa, to capture images of an eclipse that they hoped would confirm Albert Einstein's general theory of relativity.

The release of this book is timed to coincide with the 100th anniversary of their expedition, which was undertaken in tandem with another to Sobral in Brazil to confirm their results. Author Daniel Kennefick's expertise in physics makes him well placed to explain the scientific significance of both Einstein's theory and the expeditions to test it.

No Shadow of a Doubt tells of the lead up to the expeditions, details the expeditions themselves and looks at their aftermath: how Eddington and Dyson's results were received and the discussions regarding their validity. It also explores the role the expeditions played in making Albert Einstein a household name.

Where *No Shadow of a Doubt* excels is in showing the complexities involved in proving scientific theories. While we might look back now and consider Eddington and Dyson's expedition as key to 'proving' Einstein's relativity theory, Kennefick's book shows us the reality was not so clear cut. The book comes alive when discussing the timing of the expeditions and the political and religious positioning of both Einstein and Eddington during World War One – both were pacifists and internationalists at a time when almost everyone else in their countries (including those within scientific circles) was pro-war and distrustful of foreigners.

It would have been good if Kennefick had pursued a few of the tantalising hints he gives about the more diverse characters in this story. What was Mrs Einstein's research that she so resentfully had to leave when she married him? How did Eddington's mother and sister react to his letters from Principe? What did the people of Sobral and Principe make of these strange Europeans and all their cumbersome scientific equipment?



▲ One of the images of the 1919 eclipse captured during the expedition to Sobral

This is a fascinating book, full of insights into the relationship between theory and experimental proof, and the relationship between science, internationalism and war. And what better time to read it than on the anniversary of that controversial solar eclipse?

★★★★☆

***Dr Emily Winterburn** is the author of* The Stargazer's Guide: How to Read our Night Sky

Interview with the author
Daniel Kennefick

What did the expedition set out to achieve?

Einstein showed that since light has energy it must have mass. He argued that it often behaves like a particle. If light is composed of massive particles, why wouldn't it fall slightly towards the Sun as it speeds by? Starlight passing near the Sun should also be deflected by the fact that the gravitational field of the Sun distorts spacetime. Dyson pointed out that the 1919 eclipse was the ideal opportunity to find out, since the Sun would be in the middle of a particularly rich cluster of nearby stars (the Hyades) at that time.

What were their biggest obstacles?

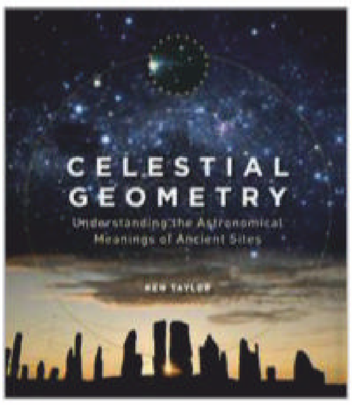
World War One was the chief obstacle. Shipping proved impossible until after the armistice was signed in November 1918, freeing up ocean liners to return to peacetime duties. The fact that the eclipse of 21 August 1914 occurred just after the outbreak of World War One also created problems. Equipment taken to Russia to observe that eclipse didn't get returned to England.

What influence did Eddington and Dyson's findings have?

There was an international outburst of enthusiasm, making Einstein world-famous almost overnight. But it was not until the birth of radio astronomy, after World War Two, that general relativity began to influence astronomy, as gravitationally collapsed objects such as quasars and pulsars were discovered. The birth of gravitational wave astronomy has made it central to the field of astronomy, as concepts like black holes finally became mainstream.

***Daniel Kennefick** is associate professor of physics at the University of Arkansas*

Celestial Geometry



Ken Taylor
Watkins Publishing
£16.99 ● PB

Whether digging down or dipping in, this stunningly illustrated book offers an unprejudiced, congenial and revelatory journey into the realms of archaeological astronomy. *Chariots of the Gods* this is not, so don't be put off by the title.

The informed and lucid narrative, suiting both young and old, casual and academic, eases you through the required principles of astronomy – the solstices and equinoxes, 'lunar standstills', the rising and setting stars. Then, suitably armed, you get to explore over 50 archaeological sites through spectacular photographs, floor plans and diagrams. It's a fascinating collection that invites you to ponder the curiosity and creativity behind the structures that are seemingly aligned with the movements of the Sun, Moon, planets and stars.

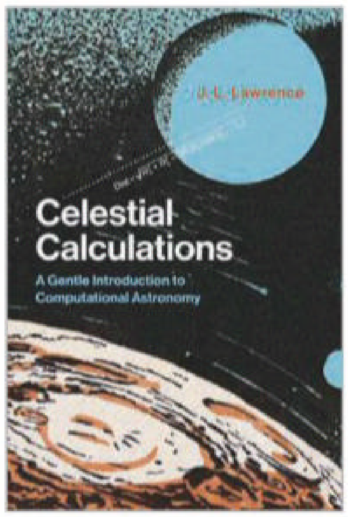
This isn't however your usual celestial geometry fare. Yes, we have Stonehenge's sarsen stones, as well as the pyramids of Egypt, Machu Picchu's temples, Easter Island and Chichén Itzá's nine-tiered Kukulcan marvel. But this book delves deeper. The lesser-known ancient, even prehistoric, megalithic structures, sacred sites and artefacts are also subject to Ken Taylor's scrutiny. Spanning Europe, North and Central America, India, Australia, Indonesia and China, Taylor's research unearths an amalgam of art, history, astronomy and mythology from star charts and tomb paintings. All reveal humankind's fascination with the heavens, whether past, present or future. Is there a connection? That's for you to decide. One thing's for sure, I want to connect with my credit card and get visiting.

★★★★★

***Jane Green** is an astronomer, presenter and author of the* Haynes Astronomy Manual

Celestial Calculations

BOOK OF THE MONTH



JL Lawrence
The MIT Press
£30 ● PB

Unless you're a mathematician, it would be natural to assume that a book about celestial calculations would make for rather dry reading. But this is far from the case, as this book is full of interesting historical and astronomical information imparted in an engaging style. There are also diagrams throughout the book to help understand the concepts being explored.

The first chapter eases you into the topic by discussing accuracy and introduces the first of the downloadable programs that accompany nine of the 10 chapters in the book. Although the programs are relatively basic, they're a welcome addition to an already useful reference, and the option of showing the intermediate calculations involved is brilliant.

Unit and time conversions set the scene for the more complex calculations discussed in the following chapters although only high school maths are required (thankfully, calculus does not make an appearance). The introduction to orbits and the co-ordinate systems that astronomers use is not for the faint-hearted, but these are absorbing topics that neatly explain the importance of knowing an observer's location on Earth.

Calculations for locating stars and other deep-sky objects are explained in depth but the discussions relating to the Sun, Moon and other Solar System objects are particularly enjoyable. These objects are mainly visible to the naked eye so confirming the results of many of the calculations is simply a matter of stepping outside with a compass. A recommended read for anyone looking to understand how we can predict where celestial objects will appear in the sky.

★★★★★

***Steve Richards** is an astro imager and author of* Making Every Photon Count

Comet: Photographs from the Rosetta Space Probe

Jean-Pierre Bibring, Hanns Zischler
Thames & Hudson
£50 ● HB

Be honest – when was the last time you printed your holiday snaps instead of just flipping through them on screen? The explosion of digital media means that many of us consume images entirely in the same format (usually as tiny pictures on a smartphone) and that goes just as much for the stunning images sent back by distant space probes as it does for our own snaps.

Some pictures, however, benefit from being given room to breathe on paper, as this new book demonstrates. *Comet* chronicles the European Space Agency's 12-year Rosetta mission to Comet 67P/Churyumov-Gerasimenko, reproducing 200 beautiful monochrome photos that capture its journey from Earth, past Mars and the asteroid belt, to rendezvous with its quarry and accompany it on its journey around the Sun.

Thames & Hudson is best known as an art publisher, so it's no surprise that the printing is immaculate throughout. Design and layout are suitably minimalist – it's the pictures that are the stars here. Brief captions provide context for each image, offering just enough information for you to get lost poring over the tiny details of 67P's geography and landscape. An introduction by Bibring, head of scientific operations for Rosetta's Philae lander, provides greater background to the mission and its aims, while artist and filmmaker Zischler's afterword reflects on the images in a wider historical context.

The forbidding price tag undeniably makes *Comet* a book for connoisseurs, but if you're someone who treasures the very finest space imagery, it could be hard to resist.

★★★★☆

***Giles Sparrow** is a science writer and a fellow of the Royal Astronomical Society*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

1 Airgo Mantua deluxe moon chair

Price £50.99 • **Supplier** Go Outdoors
Tel 0330 008 1555 • **www.gooutdoors.co.uk**

Spending hours on your feet during an observation session can be a strain. You can take the load off and sit in this folding chair, which is quilted for comfort. It comes with a carry bag for easy transportation.

2 Omegon deluxe collimation eyepiece

Price £25.90 • **Supplier** Astroshop.eu
Tel 0203 868 8042 • **www.astroshop.eu**

You can collimate virtually any Newtonian telescope using this eyepiece. It will fit into any 1.25-inch focuser and has step-by-step instructions. The eyepiece can be used with refractors and Schmidt-Cassegrain telescopes as well.

3 Feather Touch red LED astronomer's torch

Price £14.95 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

Maintain your dark adaption by using this red torch. The LED bulbs help to ensure a long battery life, while the metal casing means this torch is hard wearing. It is red light only and requires AAA batteries.

4 Celestron accessory tray

Price £25 • **Supplier** Northern Optics
Tel 01724 782022 • **https://shop.northernoptics.co.uk**

Keep your eyepieces and accessories ordered so that they're easy to find in the dark by using this tray. The organiser sits on your tripod's legs, and fits a variety of Celestron and Sky-Watcher mounts.

5 Milky Way pashmina

Price £40 • **Supplier** Present Indicative
Tel 01189 588586 • **www.presentindicative.com**

Stay warm through the night with this pashmina, which can be worn as a scarf or wrapped around your shoulders. It's printed with an 1822 chart of the Milky Way and surrounding constellations.

6 Explore Scientific eyepiece and accessory soft case

Price £25 • **Supplier** Telescope House
Tel 01342 837098 • **www.telescopehouse.com**

Carry and store all your accessories safely using this soft carry case. The partition dividers are adjustable, fixing in place using velcro, allowing you to adapt the layout to fit your own eyepiece collection.

Shaoni Bhattacharya interviews Enrique Lopez-Rodriquez

Q&A WITH AN EXTRAGALACTIC ASTRONOMER

Looking at the galactic winds around the Cigar Galaxy, M82, could reveal vital clues about how galaxies were formed in the first place

▲ **In the Cigar Galaxy, the galactic wind is dragging the magnetic field across 2,000 lightyears**

JOHANNES SCHEDLER/CCDGUIDE.COM

What is galactic wind?
Galactic winds are the flow of matter, in the form of gas and dust, expelled from a galactic plane. The plane is where most of a galaxy's matter is located. Anything outside that is intergalactic material, and anything outflowing is called winds. Usually, these are in the polar directions, perpendicular to the galactic plane.

Why did you study M82?
In this 'starburst' galaxy, the core contains a huge star formation region that is collapsing matter dominated by gravitational forces to form new stars. It pushes matter outside the galaxy through outflows.

From an observational point of view, M82 is very close and bright, while, from a scientific viewpoint, it's one of the most powerful and most violent star formation galaxies in the nearby Universe.

For studies of galaxy evolution, you need to set baselines. As well as studying galaxies that are not active in star formation, you need to study those at the other extreme, dominated by star formation. This will allow us to stretch the basics of our knowledge, in order for us to study more complex galaxies further away from Earth, from earlier in the Universe.

How do you go about studying galactic winds?
We used SOFIA (the Stratospheric Observatory for Infrared Astronomy), an airborne observatory with a 2.5 metre-telescope fitted on a Boeing 747. SOFIA studies the thermal emission of objects in the Universe – the light absorbed by dust and then emitted again at a specific temperature.

In our new published study we used a new instrument called HAWC+ (High-resolution Airborne Wideband Camera+). This studies the effect of the magnetic field on the dust. We cannot measure the magnetic field itself because we would need to be in situ, but we can study its indirect effect on matter.

If there is a magnetic field and it's strong enough, it will change the overall direction of the dust so it aligns in one direction. HAWC+ detects the signature of grains affected by the magnetic field.

Enrique Lopez-Rodriguez is a scientist on SOFIA and instrument scientist of HAWC+, based at NASA's Ames Research Center in California

We hypothesised the outflows needed to do something with the magnetic field of the Cigar Galaxy.

What did you find?
We flew for three hours, with two hours of observations. Half an hour after these began we saw the signature of the magnetised dust grains along the direction of the galactic winds. We saw the effect that was theoretically predicted in the magnetic field of the outflows. We viewed the signature of the aligned dust grains following the direction of the galactic wind – not just in the direction of the galaxy's plane. The wind is dragging the magnetic field across 2,000 lightyears.

Now we have this data point, it means we can look at younger galaxies. Do we see these effects in the galaxies that are being created in the early Universe? If not, what's the difference between them and how does that change with galaxy evolution?

How might galactic winds seed galaxies?
We have several theories of how galaxies form, and we know that in their evolution they need to interact with each other by dragging matter and changing the gravitational force. We also know that magnetic fields are everywhere in the Universe, the only difference is the strength. When you look at the magnetic field in the intergalactic medium, it is insignificant. So somehow the galaxy is magnifying the magnetic field due to the flow of matter within it.

Our results are telling us that galactic winds are able to drag the magnified magnetic field into the intergalactic medium. If you have galaxies interacting, you have a strong magnetic field that may influence galaxy evolution in the early stage of the Universe.

What's next in understanding galaxy evolution?
This is the first and only result we have. We will examine more galaxies to see if we can see this effect again. In a year or two we will have a sample of 15 or 20 galaxies which will give us more of an idea of how intergalactic winds and magnetic field interactions affect galaxy evolution.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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Rising high in the night sky, bright Jupiter offers views of its moons and Great Red Spot

When to use this chart

1 Jun at 24:00 AEDT (13.00 UT)
15 Jun at 23:00 AEDT (12.00 UT)
28 Jun at 22:00 AEDT (11.00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JUNE HIGHLIGHTS

Jupiter is at opposition in June, presenting its brightest and largest image for the year. Being near a maximum negative declination it transits high in the Southern Hemisphere, minimising the amount of atmosphere we (Down Under) need to look through. Being up all night gives more time to observe the dance of the four Galilean moons as they move across Jupiter's disc. The Great Red Spot is best seen one hour either side of its transit across the Jovian meridian.

STARS AND CONSTELLATIONS

In the northern evening sky, nestled between the kite of Boötes and the butterfly of Hercules, lies a constellation of seven stars arranged in a semicircle (7° in diameter). Although faint, the asterism is obvious to the naked eye under dark skies. It's most prominent (alpha) star, 2nd magnitude Alphecca means 'broken' – referring to the circle. Its other name, Gemma (Latin for gem), alludes to the identity of this group – it's the jewel in the Northern Crown of Corona Borealis.

THE PLANETS

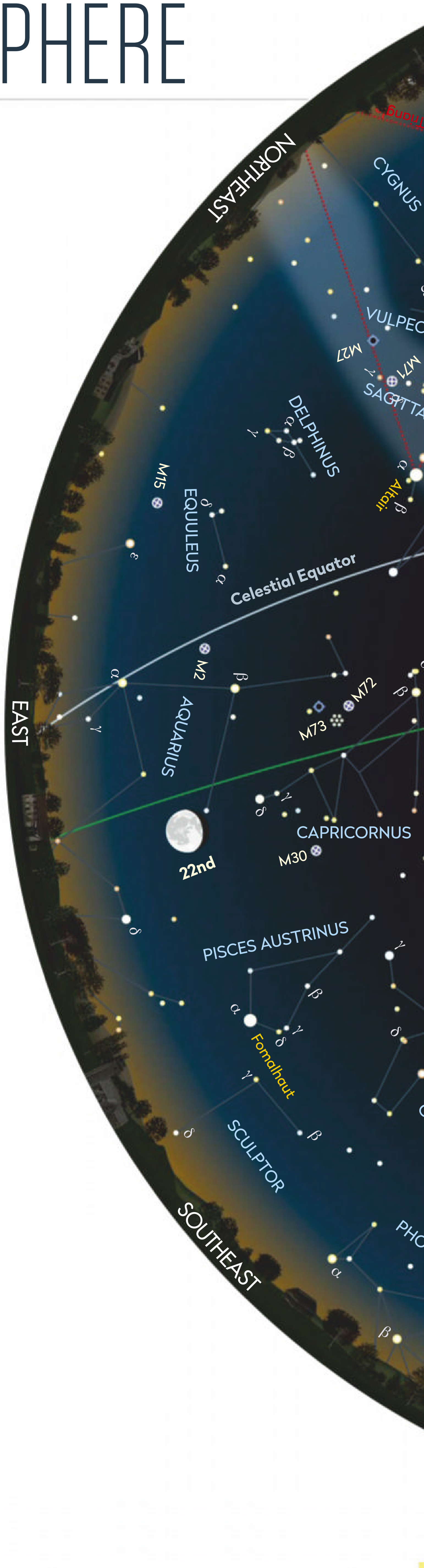
Jupiter dominates the night sky, rising around sunset midmonth, with Saturn following two hours later. The northwestern twilight sky is home to Mars, with Mercury rising out of the solar glare to join the Red Planet in June's latter half. On 18 June the planets are only 0.4° apart. Turning to the morning, Neptune rises about midnight and transits around sunrise, with Uranus following. The beacon of Venus, slowly leaving the morning sky, is visible in the eastern dawn.

DEEP-SKY OBJECTS

This month we go on a visit to Hercules, commencing with Alpha Herculis (RA 17h 14.6m, dec. +14° 24'). This impressive double star is located in the far south of this constellation, just under the Coffin asterism in Ophiuchus. Its mag. +3.5 primary, Alpha Herculis A, is a distinctive orange colour having a green, mag. +5.4 companion, Alpha Herculis B, 5 arcseconds away.

Only 2.5° south of the naked eye star Eta Herculis is the globular star cluster NGC 6205 or M13 (RA 16h 41.7', dec. +36° 28'). Although attracting accolades from Northern Hemisphere observers, this (mag. +5.7) globular is well above the horizon for mid-latitude Australian winter evenings. It has a large bright core dropping off to an uneven halo, extending the cluster to around 20 arcminutes in diameter.

CHART: PETE LAWRENCE




NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
HERCULES
M92
Vega
LYRA
M57
Summer
Keystone
M13
Albireo
CORONA BOREALIS
BOÖTES
Kite
Alphecca/Gemma
Arcturus
COMA BERENICES
M3
M53
Rasalgethi
Rasalhague
OPHIUCHUS
SERPENS CAPUT
AQUILA
SERPENS CAUDA
M5
Realm of Galaxies
M100
M60
M58
M87
M86
LEO
VIRGO
M61
10th
M14
M10
M12
M107
SCUTUM
M11
M16
M17
M18
M23
M9
16th
13th
Ecliptic
Spica
LIBRA
Jupiter
M4
Antares
M104
CORVUS
Saturn
M20
M8
M75
19th
M6
M7
Teapot
SAGITTARIUS
SCORPIUS
Fish Hook
M83
M68
CRATER
CORONA AUSTRALIS
TELESCOPIUM
ARA
NORMA
Rigel Kent
LUPUS
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INDUS
CIRCINUS
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CRUX
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PAVO
APUS
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CHAMAELEON
GRUS
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47 Tucanae
South Celestial Pole
VELA
SMC
MENSA
HYDRUS
VOLANS
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PARABOLIC DOBSONIANS
Sky-Watcher®
All these Sky-Watcher Dobsonian Models feature High Quality Parabolic Primary Mirrors to eliminate spherical aberrations.
The mirrors are 'parabolised' to bring all the light rays to the same focal point to produce sharp, contrasty images, which are full of detail.
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Prod.Code 10245
SRP £109
HERITAGE-130P
FLEXTUBE™
5.1" (f/5)
Prod.Code 10213
SRP £169
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SRP £219
SKYLINER CLASSIC DOBSONIANS
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200P 8" (f/5.9) Prod.Code 10717 SRP £339
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Skyliner-300P FlexTube™
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"Despite their great performance to cost ratio, Dobsonians can be rather bulky in larger apertures, but Sky-Watcher have addressed this with their innovative and aesthetically-pleasing Flextube™ range. With their collapsible tube design, these versatile instruments are easy to store and can be readied for observation at a moments notice. Ideal for deep-sky viewing, these scopes will also deliver stunning planetary images"
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350P 14" (f/4.5) Prod.Code 10227 SRP £2149
400P 16" (f/4.4) Prod.Code 10231 SRP £2699
StarGate-450P Parabolic Truss Tube Dobsonian
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